Laboratory Manual of A Year in Science

Thalman and Weckel

LABORATORY MANUAL

OF

A YEAR IN SCIENCE

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PREFACE FOR THE LABORATORY MANUAL

Laboratory work is an essential part of any course in science. The mental development acquired by pupils performing a series of experiments, interpreting their results, and carefully recording them, is of equal, if not more value, than the mere accumulation of facts. We cannot justify the existence of any course in the high school which has the acquiring of information as its only purpose. The performance of experiments is not a mechanical part of the course in which the use of the intelligence of the pupil plays no part. Too much emphasis can not be placed upon the fact that the pupil must perform experiments intelligently, using his head as well as his hands. Frequently beginners are inclined to think that laboratory work is merely entertaining.

The following outlines for experiments are the result of about fifteen years of experiment and search for interesting and fundamental scientific matter adapted to the age and preparation of pupils entering the high school. During this period of experimentation from six to nineteen classes a year have pursued this course. It has thus been tried on thousands of students under the direction of many teachers. We gratefully acknowledge our indebtedness to these teachers for their many valuable suggestions and criticisms.

Since first year pupils have had no training in scientific methods, the experiments must necessarily be short and simple. As far as possible, the following experiments should be performed by the pupils, working individually, or, if necessary, in small groups. We are convinced that the training acquired by pupils in this way is much greater than that obtained when the teacher demonstrates all of the experiments. With the expenditure of a very small amount of money, it is possible to purchase the apparatus necessary for the equipment of a laboratory for individual experimentation.

Supplementary or alternative exercises are frequently given. Since both experiments in such cases develop or illustrate the same principle, it is not essential that both be performed. Pupils should also be encouraged to devise experiments of their own. If the laboratory sections are very large, this latter feature is impractical.

During the first part of the course it is advisable for the teacher to read carefully the *Directions* with the pupils. There are always some members of a class who acquire with difficulty the ability to read, interpret, and follow directions intelligently. A note book kept by each pupil should contain records of most of the experiments performed. The record of each experiment should include:

1. An account of the *method* used in performing the experiment.

2. A simple diagrammatic drawing of the apparatus used.

3. A statement of the *results.*

4. A *conclusion* drawn from the results, when a conclusion is possible.

It is essential that these notes are clearly and concisely expressed and neatly kept.

The development of this laboratory course could not have been made possible except for the encouragement, sympathetic interest, and faith of Mr. J. C. Hanna, to whom we hereby acknowledge our indebtedness.

CONTENTS

APPARATUS

The following lists contain all the apparatus and supplies necessary for a satisfactory presentation of the laboratory exercises given in this manual. Many of the most expensive pieces of apparatus, marked with an asterisk in the following lists, may be eliminated without requiring the omission of many exercises. In many cases it is possible to substitute simple improvised apparatus for these more expensive pieces.

A school equipped for laboratory work in physics and chemistry is equipped, also, for a general science course. The expense of equipping a laboratory for general science will be nominal, if the equipment in the other laboratories in the school can be used.

The following named apparatus can be obtained from dealers in laboratory supplies. The prices given here are only approximate. Any school can secure a discount of from 10 to 25 per cent from these prices.

A. PHYSICAL APPARATUS

1. For demonstration work, one set for the whole class.

*1 air pump	$10.00	3 animal membranes	.30
2 balances, spring	1.00	1 bar compound	.50
*1 balance and weights	9.08	1 blow pipe	.14
1 ball and ring	1.00	1 brass globe, hollow	2.25
1 balloon, rubber	.06	2 clamps, burette	.16

1 cotton roll	.20	1 porous cup	.14
3 deflagrating spoons...	.30	*1 pneumatic trough ...	.81
3 dry cells	1.05	1 ring stand	1.12
*1 drying oven (household type may be used)	5.50	1 rubber dam, 1 sq. ft..	.30
1 pk. filter paper......	.15	1 shears	.67
*1 Magdeburg hemisphere	3.00	1 ft. tubing, rubber, $\frac{3}{16}''$	.18
2 magnets	.45	1 ft. tubing, rubber, $\frac{1}{8}''$	.12
2 metric sticks	.50	1 twine	.05
2 mortars and pestles..	.40	Total	$39.73
1 pan, dissecting	.20	Total not essential, marked with an asterisk	28.39
1 pinch cock	.10	Total, essential	11.34

The above list does not include several expensive pieces of apparatus which are not used frequently enough to justify placing them in the list. They are: a barometer, a compound microscope, a skeleton, and an anatomical manikin, or models of the principal organs of the body.

2. For individual work, one set for each pupil, or for each group of pupils.

1 asbestos sheet, 8 x 8 x $\frac{1}{16}''$	$0.10	1 metric rule	.03
1 Bunsen burner (alcohol lamp may be used)	.22	2 needles, dissecting	.12
1 test tube clamp.......	.07	1 ring stand and rings..	.54
1 forceps	.10	1 scalpel	.25
1 lever holder	.18	1 test tube rack........	.38
		1 wire gauze 5 x 5''....	.05
		Total	$2.04

B. GLASSWARE

1. Demonstration, one set for the whole class.

2 battery jars	$1.00
*1 belljar, closed ground glass stopper....	1.50
*1 burette, 100 c.c.	1.80

1 pk. corks	.35
$\frac{1}{4}$ oz. round cover glasses	.30
*1 crystallizing dish, 10″	1.00
2 cylinders, glass, 3 x 15″	1.66
*1 electrolysis apparatus	5.00
1 graduate, 100 c.c.	.56
1 glass plate, 10″	.25
2 doz. slides, microscopic	.25
5 thistle tubes	.40
1 torricellian tube	.28
$\frac{1}{2}$ lb. glass tubing, $\frac{3}{16}$″	.22
Total	$14.57
Total, not essential	9.30
Total, essential	5.27

2. Individual, one set for each pupil, or for each group of pupils.

2 beakers, 230 c.c.	$0.30
2 bottles, wide mouth, 8 oz.	.10
1 evaporating dish	.25
2 flasks, 16 oz.	.36
1 funnel	.20
1 petri dish, 100 mm. diam.	.25
1 plate, 3″	.05
1 stirring rod, glass, 5 x $\frac{3}{16}$″	.02
1 set stoppers, rubber	.50

No. 3, 1-hole	No. 8, solid
No. 3, 2-hole	No. 8, 1-hole
No. 2, 1-hole	No. 8, 2-hole

12 test tubes, 6 x $\frac{5}{8}$″	.25
1 test tube, hard, 6 x $\frac{3}{4}$″	.10
1 test tube brush	.05
1 thermometer, 10° to 210° C.	1.25
1 tumbler, glass	.04
Total	$2.72

C. CHEMICALS

The amount of each chemical will vary with the size of the class, but the total cost of chemicals will not exceed $12.00.

*Acetic acid
Alcohol
Ammonium hydroxide (household ammonia)
Charcoal
Chloroform
*Cobalt chloride
Copper, sheet
Copper sulphate
Eosin (red ink may be substituted)
*Ether
Fehling's solution, No. 1 and No. 2
Flax seed, ground
Hydrochloric acid
Iodine
Iron filings
Iron wool
Lime water (made by slacking lime in water and filtering off water)
Litmus paper, red and blue
Manganese dioxide
Marble
Mercury
*Mercuric chloride
Mercuric oxide
Molasses
Nitric acid
Oxalic acid
Olive oil
Pancreatin
Paraffin
Pepsin
Phosphorus, red
Phosphorus, yellow
Potassium chlorate
Potassium iodide
*Potassium oxalate acid
*Potassium permanganate
Rennet
Salt
Sodium hydroxide
*Sodium hyposulphite
Sodium nitrite
Starch, corn
Sugar, cane
Sugar, grape
Sulphur, flower
Sulphur, roll
Sulphuric acid
Vaseline
Zinc, granulated or scrap
Zinc, sheet

D. SUMMARY OF COST OF EQUIPMENT

1 complete set of apparatus for demonstration..	$16.61
1 complete set for individual use...............	4.76
1 set of chemicals, not over....................	12.00
Total	$33.37

LABORATORY MANUAL

OF

A YEAR IN SCIENCE

CHAPTER I

MATTER

Exercise 1. Does Gas Occupy Space?

Object: To determine whether air, which is a gas, occupies space.

Apparatus

Glass tumbler
Large glass jar
Wide mouth bottle
Two-hole rubber stopper
Thistle tube
Glass tubing
Rubber tubing
Clamp

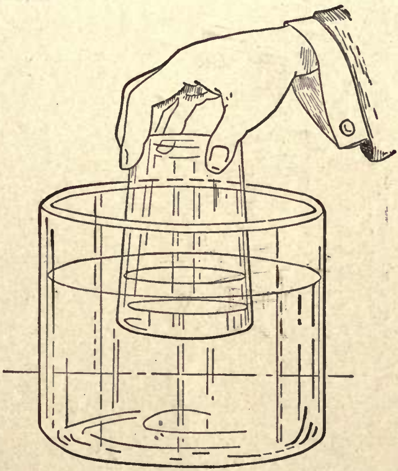


Fig. 1.

Directions: A. Fill the glass jar three-quarters full of water. Push the tumbler, mouth downward, half way under the sur-

face of the water. Does the water rise to fill the tumbler? Does it rise into the tumbler at all? Now tilt the tumbler sidewise so that the edge of the mouth of the tumbler comes just above the surface of the water. What happens? Without removing the tumbler, push it down into the water again. Does the water rise into the tumbler this time? In the first instance was the tumbler empty? What did it contain? What do you conclude concerning this substance?

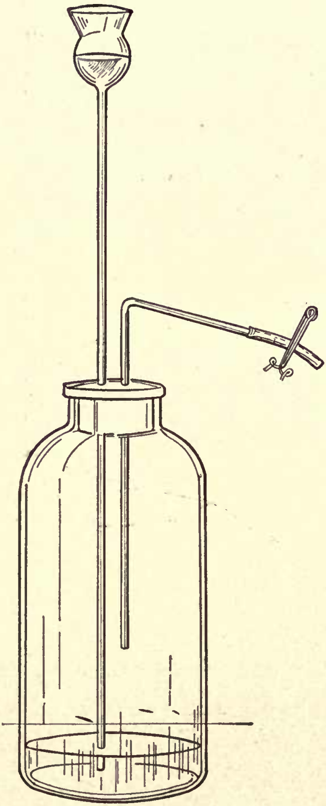


Fig. 2.

B. Put the stem end of the thistle tube through one of the holes of the rubber stopper. Into the other hole, insert the piece of glass tubing. Place the stopper in the mouth of the bottle and close the upper end of the glass tube by means of the rubber tubing and clamp. Now pour water into the bulb of the thistle tube. Does any water run into the bottle? Keep the bulb full of water. Does the

water continue to run into the bottle? Open the clamp. What happened? How do you account for the results?

Exercise 2. Comparison of English and Metric Systems.*

Object: To compare the English and metric systems.

Apparatus

Compass	English weights
Metric rule	Quart measure
English rule	Liter measure
Metric weights	Centigrade thermometer.

Directions: A. Comparison of the English and metric units of length.

Use a compass with sharp steel points, a metric rule, and an English rule. Accurately get the space of an inch with the compass. Place the compass on one of the centimeter lines (not the end of the rule) of the metric rule and read as accurately as you can, estimating in tenths of millimeters the distance of the inch. Record in a tabular form. Now get the space of two inches and read the corresponding distance on the metric rule. Do the same for 3, 4, 5, 6, 7, and 8 inches. Average each reading to find the number of centimeters in an inch. Get the general average of all your results. Get the correct value from the instructor or a physics book.

*A preliminary exercise for those teachers who wish to acquaint the pupils with the units of measure before undertaking the main work of the course.

What error did you make? What is the reason for the error?

B. Measurements.

Accurately measure the length, width, and thickness of the top of the laboratory table, using the metric rule. Calculate the area of the top in square centimeters and in square meters. Also calculate the number of cubic centimeters in the table top. Change all of these metric readings into English values. Make the same measurements, using the English rule. Find the area of the table top in square inches, square feet and square yards. Compare all of these results with your calculated results.

C. Examine a box of metric weights. Study the small or fractional weights.

What relation do these small weights have to a gram weight? Arbitrarily select six different combinations of small and large weights and express each of these values in grams. Have the instructor verify your readings.

D. Comparison of the English and metric units of weight.

(a) Weigh a one pound weight as accurately as you can, using metric weights. Record your result.

(b) Weigh a two pound weight in the same way. Find the average of both readings. How many grams in a pound?

(c) Weigh an ounce to find the number of grams to which it is equivalent. Get the correct values from

the instructor. How much of an error did you make? How do you account for this error?

E. Comparison of the English and metric units of volume.

Use a liter vessel, a quart measure, and a set of metric weights.

(a) Find by measurement, using water, which is larger, a liter or a quart.

(b) Weigh a liter of distilled water. First balance the dry liter vessel, then fill with distilled water and weigh. Find the temperature of the water with a centigrade thermometer.

(c) Weigh a quart of distilled water. Use the same method as you employed in weighing the liter of water.

(d) Find the relation of a quart to a liter from your data of (e). Ask the instructor to verify your results. How accurate has your work been? Does the temperature of the water have anything to do with its weight? Can you think of reasons for any errors that you may have made?

Exercise 3. Does Gas Have Weight?

Object: To determine whether gases have weight.

Apparatus

Balance and weights
Hollow brass globe with stop cock
Air pump
Incandescent lamp bulb (burnt out bulb)
Bunsen burner
Blow pipe

Directions: A. On one pan of the balance place the brass globe. Upon the other pan place enough weights

to balance the globe evenly. Without disturbing the weight pan, remove the globe from the other pan.

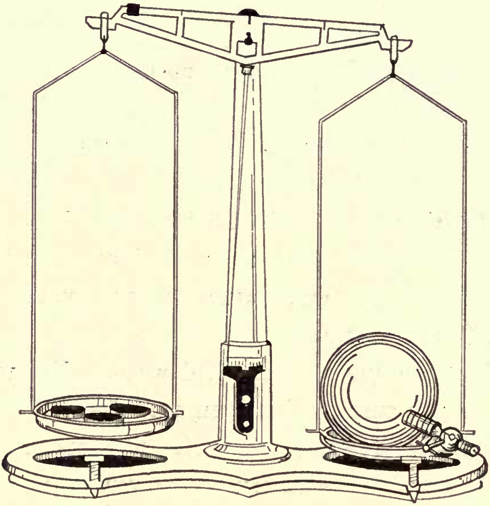


Fig. 3.

With an air pump exhaust the air from the globe and then close the stop cock. Then replace the globe on the pan of the balance from which it was removed. Do the two sides now evenly balance each other? How do you account for this condition? Does air then have weight? Air is a gas. From the definition of matter, do experiments 1 and 3 prove that gas is matter? Why?

B. The bulb of an incandescent lamp is empty save for the filament and a very slight trace of gas which was not exhausted. Weigh the bulb carefully and accurately With the aid of the blow-pipe direct a

tiny flame point of the Bunsen flame upon a small area of the bulb near the top where the diameter is greatest. As the glass softens, the pressure of the air

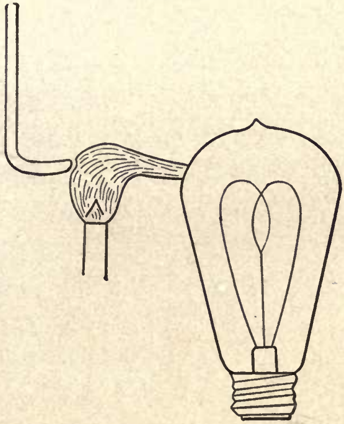


Fig. 4.

outside will make a hole. Weigh the bulb after the hole has been made in the glass.

Observations:

Weight of empty bulb ....

Weight of bulb filled with air ....

Difference equals weight of air in bulb ....

CHAPTER II

CONSTITUTION OF MATTER

Exercise 4. Diffusion of Liquids.

Object: To determine whether liquids will diffuse when in contact.

Apparatus

Thistle tube
Glass cylinder
Metric rule
Saturated solution of copper sulphate
Distilled water

Directions: Fill the glass cylinder two-thirds full of distilled water. Into the cylinder place the thistle tube with the bulb upward. When the water is quiet, slowly pour through the thistle tube 50 cubic centimeters of copper sulphate solution. This must be done as carefully as possible to avoid mixing the liquids. What is now the relative positions of the liquids? Is there a sharp line of separation between the liquids? Why is the copper sulphate solution placed on the bottom of the glass cylinder? Measure accurately with a metric rule the height of the copper sulphate solution. Record observations and allow the experiment to remain undisturbed until the next recitation period. Then repeat the observations made above. What changes? In conclusion, what have you learned from this experiment?

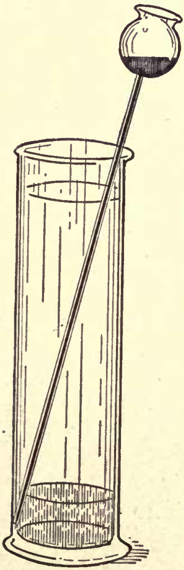


Fig. 5.

Exercise 5. Diffusion of Liquids through a Membrane.

Object: Will liquids diffuse if separated by an animal membrane?

Apparatus

Animal membrane
Thistle tube
Water
Molasses
Twine
Glass jar
Ring stand and clamp
Rubber tubing
Clamp
Card board
Egg
Glass tubing
Sealing wax
Hydrochloric acid
Glass tumbler
Bunsen burner

Directions: A. Over the stem end of the thistle tube fit a small piece of rubber tubing. Close this tightly with a clamp. Fill the bulb of the tube with dilute molasses. Over the end of the bulb securely tie an animal membrane, being careful to exclude all air bubbles. From the ring stand suspend the tube with the bulb in a jar of water. Mark the level of the molasses in the tube. Note the color of the water in the jar. At the end of one hour repeat the same observations. Observe again at the end of twenty-four hours. What changes have taken place? Has any molasses passed into the water? How do you know? Has any water passed into the molasses? In which direction has diffusion taken place more rapidly? How do you know?

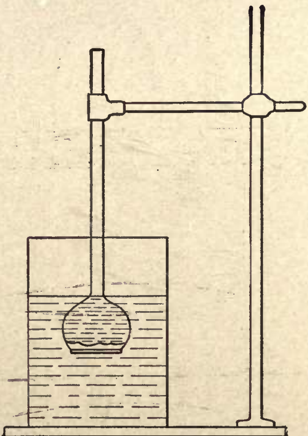


Fig. 6.

B. In the cardboard cut a hole large enough so that

the large end of the egg will extend about ¾ of an inch below the cardboard. On the small end of the egg break away the shell to form an opening large enough to insert the glass tube, which should be about 6 inches long. Carefully seal the tube in the egg with the end projecting about half an inch below the shell. Fill the tumbler with hydrochloric acid. Place the cardboard and the egg over it with the large end of the egg projecting into the acid. The acid gradually dissolves the shell, exposing the thin membrane underneath it. When the shell has been removed from the end of the egg, empty the acid and fill the beaker with water. Rinse the acid off the egg and replace the cardboard and egg over the tumbler. The water in the tumbler and the contents of the egg are now separated by the egg membrane. Allow the experiment to stand for 24 hours. What change do you note in the tube? How do you account for this change?

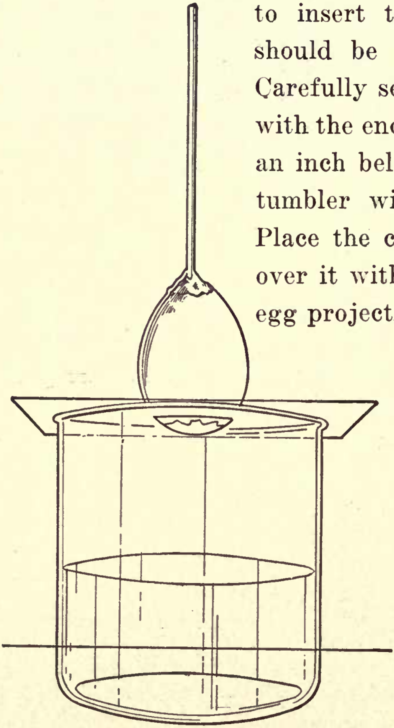


Fig. 7.

Exercise 6. Diffusion of Gases.

Object: Will gases diffuse when in contact?

Apparatus

Gas generator	Wide mouth bottles
Lime water	Glass covers

Directions: From a gas generator fill a bottle with carbon dioxide.* Carbon dioxide is heavier than air and so displaces the air which was in the bottle. Pour lime water into the bottle. By shaking the bottle thoroughly, mix the lime water with the carbon dioxide. What change do you note in the lime water? Such a change in lime water indicates the presence of carbon dioxide. From the generator fill another bottle with carbon dioxide. Cover the bottle with a glass plate and remove it to your desk. Over the mouth of this bottle invert a bottle of air and then remove the glass plate. Allow the bottles to stand in this relation five minutes. Remove the upper bottle and cover it immediately with the glass plate. Is there any carbon dioxide in the upper bottle? How do you determine this? What does this show?

Fig. 8.

*To generate carbon dioxide, place a few small pieces of marble in a flask and cover with dilute hydrochloric acid. The flask should be fitted with a delivery tube through which the gas can pass into the wide mouth bottle.

Exercise 7. Diffusion of Gases. (Demonstration.)

Object: Will gases diffuse through a porous wall?

Apparatus

Porous cup with glass tube inserted
Ring stand
Cup of colored liquid
Belljar
Air pump

Directions: From the ring stand suspend the porous cup apparatus with the free end of the glass tube projecting into the cup of colored liquid. Place the belljar over the porous cup. Is there any change at the end of the glass tube in the colored liquid? With an air pump force air into the belljar over the porous cup. Is there any change now at the end of the glass tube in the colored liquid? Thus the air currents have no effect. Fill the belljar with illuminating gas, then quickly lower it over the porous cup. What change takes place at the end of the glass tube in the colored liquid? Remove the belljar. What change do you now observe? In the first instance what were the bubbles escaping? Where did they come from? What must have been the condition in the porous cup

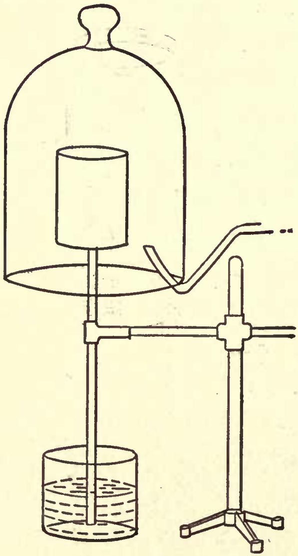


Fig. 9.

to produce such a result? How do you account for it? What must have been the condition to cause the liquid to rise in the tube when the belljar was removed? What does this exercise teach? Compare the rate of diffusion of gases with that of liquids; of solids. Compare the rate of diffusion of liquids with that of solids.

Exercise 8. Mixing of Alcohol and Water.

Object: To determine the result of mixing equal volumes of alcohol and water.

Apparatus

Alcohol 96%	Burette, 100 c.c.
Distilled water	Clamp

Directions: Over the small end of the burette place a small rubber tube. Close the tube tightly with the clamp. Into the open end of the burette pour distilled water to the height of the 50 c.c. mark. Then carefully and slowly pour into the tube 50 c.c. of alcohol. Note carefully the height of the two liquids. By means of the thumb close the burette and mix the liquids thoroughly by repeatedly inverting the tube. Observe again the height to which the liquids rise. What does this condition show? How do you account for it?

CHAPTER III

EFFECT OF HEAT ON MATTER

Exercise 9. Effect of Heat on Solids.

Object: To determine the effect of the change of temperature on the volume of a solid.

Apparatus

Brass ball	Compound bar
Brass ring	Nail punch
Bunsen burner	Screw nut

Directions: **A.** Try the fit of the ring over the ball. Heat the ball. Will the ball now pass through the ring? Heat the ring. Will the ball now pass through the ring? Cool the ring by running tap water over it. Will the ball pass through the ring now? In the same manner cool the ball and try the fit again. From these observations what is the effect of an increase of temperature upon the volume of a solid? What is the effect of a decrease of temperature?

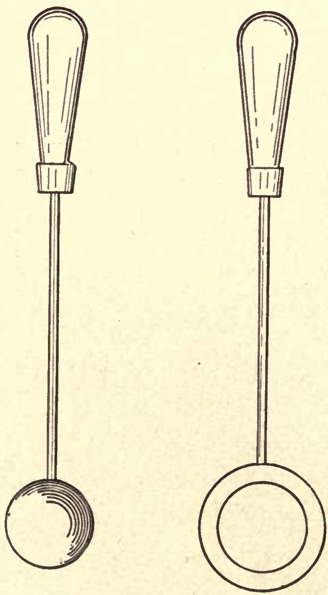


Fig. 10.

B. Adjust the nut on the punch. Mark the point

on the punch to which the nut fits. Then heat the nut and adjust it on the punch once more. Does it pass as far or farther on the punch than it did when cold? Heat the punch and repeat the adjustment. What do you find? What does this show? Have you ever seen a blacksmith fit a tire to a wagon wheel? What is the principle involved?

C. Do all solids expand and contract at the same rate? To determine this, use a compound bar. A compound bar consists of two metals tightly welded or riveted together lengthwise. Heat the bar equally on both sides by playing the flame of a Bunsen burner along its edge. Do you observe any change in the direction of the bar? What does this indicate? Cool the bar by running tap water over its edge. Does the direction of the bar now change? How do you explain these results?

Exercise 10. Effect of Heat on Liquids.

Object: Does the volume of liquids change with a change in temperature?

Apparatus

Test tube	Bunsen burner
One-hole rubber stopper	Test tube clamp
Glass tube	

Directions: A. Fill the test tube with cold water. Into the mouth of the tube insert the rubber stopper fitted with a glass tube. Press on the stopper until the water rises about an inch in the glass tube. Mark carefully the level of the water.

Heat the water gently by playing the flame of the Bunsen burner along the side of the test tube. What change do you observe in the water level?

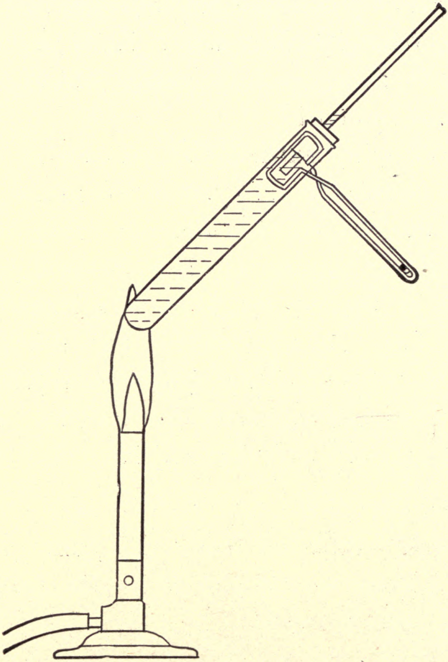


Fig. 11.

Again mark the level of the water. Cool the water in the test tube by running tap water over it, or by surrounding the test tube with ice. After a few minutes note the level of the water.

B. Fill the test tube with water. Tightly cork the filled tube and after thoroughly drying the exterior of the tube, gently heat it over the Bunsen flame. Explain

the result. Did the amount of water increase with the increase of temperature? Did it decrease with a lower temperature? Then how do you explain the increase and decrease in volume noted upon heating and cooling respectively?

Exercise 11. Effect of Heat on Gases.

Object: To determine the effect of a change of temperature upon the volume of gases.

Apparatus

Test tube	Beaker of colored liquid
One-hole rubber stopper	Test tube clamp
Bunsen burner	

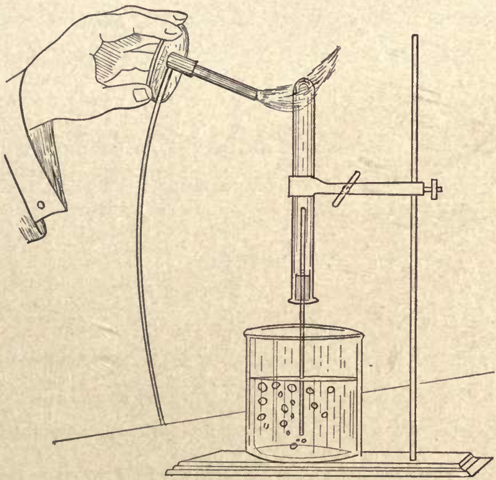


Fig. 12.

Directions: **A.** Fit the stopper with the glass tube into the test tube as in the preceding exercise. With what is the test tube filled? Is this a gas? See Exercise

1. Place the projecting end of the glass tube into the beaker of colored liquid. Heat the tube gently with a Bunsen flame. Observe carefully all changes. Without changing the apparatus allow the gas in the test tube to cool. What change do you now observe? How do you account for the change?

B. Tightly cork a test tube filled with air. Gently heat the tube over the Bunsen flame. Explain the result. Does this change indicate an increase in the amount of gas in the test tube or in its volume? From the last three exercises what is the effect of the increase of temperature upon the intermolecular spaces? Upon the molecules? The effect of the decrease of temperature upon the intermolecular spaces? Upon the molecules?

Exercise 12. Cohesion, Adhesion, and Gravity.

Object: A study of forces acting between molecules and between masses.

Apparatus

Spring balance	Battery jar
Circular glass plate	Sealing wax

Directions: By means of sealing wax, attach three strings at equidistant points near the margin of the glass plate. Tie the ends of the strings together and suspend the plate from the hook of the spring balance. (The glass plate must hang horizontally.) Record the weight of the glass plate. Then lower the apparatus over the battery jar filled with water, until the plate touches the water. Slowly lift the balance, at the

same time noting any changes in the reading on the index of the balance. Continue to lift the balance. What happens? Examine the under surface of the plate. What do you find there? Does this indicate that the plate was separated from the water or that the water particles were pulled apart?

Thus it will be seen that two forces were acting, the one holding the molecules of water together, called cohesion, the other holding the plate to the water, adhesion. Which in this experiment was the greater? With the water still adhering, hold the plate in a vertical position. What happens to the water? This third force causing the water to drop is called gravity.

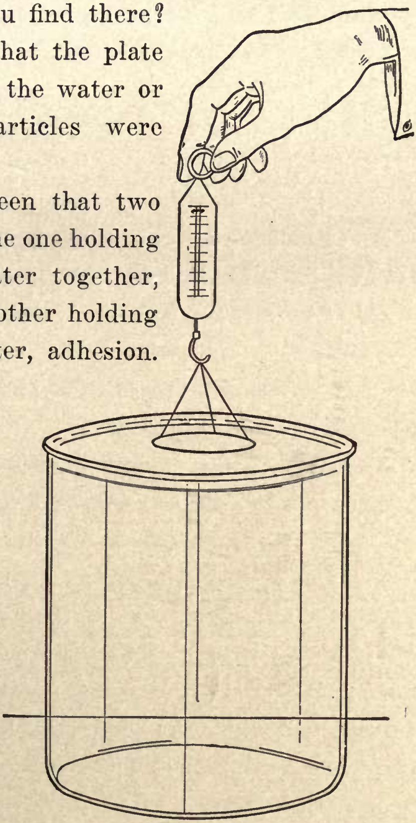


Fig. 13.

Which of these forces acts between molecules of the same kind? Between molecules of different kinds? Between masses?

CHAPTER IV

MEASUREMENT OF TEMPERATURE

Exercise 13. Thermometers.

Object: A comparative study of thermometers.

Apparatus

Fahrenheit thermometer
Centigrade thermometer
Metric rule

Directions: Examine a thermometer carefully. How is it made? Note the markings on the scale. What do they indicate? What two points on the thermometer seem of special importance? On this, the centigrade thermometer, zero degree is the freezing point of water and 100 degrees the boiling point. Can you suggest a way of determining these points? After they are located how would you find the length on the scale of one degree?

On your note paper make a drawing of a thermometer. On the right side of the line place two points, one for the boiling point, the other for the freezing point. Between these points mark the 10, 20, 30, etc., to 100 degrees. Continue the line representing the thermometer tube below 0 degrees far enough to admit negative 40 degrees. On the left side mark 212 degrees opposite boiling and 32 degrees opposite freezing. How many degrees on this, the Fahrenheit thermometer, are there between freezing and boiling? On

the side opposite the 10, 20, 30 (degrees), etc., markings of the centigrade thermometer, fill in the corresponding numbers of the Fahrenheit thermometer. Find the value of one degree centigrade in terms of Fahrenheit degrees. Find the value of one degree Fahrenheit in terms of the centigrade degree.

Problems: 1. Fifteen degrees C. are equal to how many degrees F.?

2. Forty-five degrees F. are equal to how many degrees C.?

3. The centigrade thermometer registers 21 degrees. What does the Fahrenheit thermometer register at the same time?

4. The Fahrenheit thermometer registers 14 degrees. What does the centigrade thermometer register at the same time?

5. What is the principle upon which the construction of the thermometer is based?

Exercise 14. Measurement of the Heat of a Flame.

It is a well-known fact that if any substance is held in a flame, its temperature is increased. The cause of this increase is called heat. To measure this increase some unit of measure is necessary. To this unit the name gram-calorie has been given. *A gram-calorie is the amount of heat necessary to raise one gram of water one degree centigrade.*

Object: To determine the amount of heat given off by a given flame in one minute.

Apparatus

Flask	Wire gauze
Thermometer	Bunsen burner
Asbestos cover for flask	Ring stand
Flame protector	Graduate, 100 c.c.

Directions: A. Place 100 c.c. of water in the flask and set it aside. From the ring stand suspend the flame protector. Adjust it in such a manner that the lower part of the protector fits over the upper part of the Bunsen burner. Then place the wire gauze upon the ring. Light the Bunsen burner and regulate the gas and air for a blue flame of moderate size. Place the burner under the protector. Do not change these adjustments until the experiment is completed.

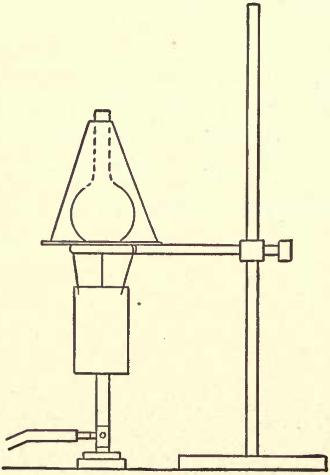


Fig. 14.

Take the temperature of the water in the flask. Cover the flask with an asbestos cover, and place it on the wire gauze, noting the exact time this is done. Note and record the rise in temperature of the water each minute for ten minutes. Then turn off the gas.

What is the average number of degrees of rise of temperature per minute? How many c.c. of water were

increased this number of degrees per minute? Then how many calories of heat was your flame giving off per minute?

Tabulate results as follows:

Am't of Water	Temp.	Time	Inc. per min.	Ave.Inc.
Beginning		1		
		2		
		3		
		4		
		5		
		6		
		7		
		8		
		9		
End		10		

B. With the gas adjustment the same throughout, prepare flasks as follows:

One	containing	100 c.c.	water.
"	"	200 c.c.	"
"	"	300 c.c.	"
"	"	400 c.c.	"
"	"	500 c.c.	"

The water in each flask should be the same temperature (room temp.) at the beginning of the experiment. With the bulb of the thermometer in the water in the flask, heat each until the water begins to boil. Note carefully in each instance the length of time necessary

to bring each separate quantity to the boiling point. The product of the quantity of water multiplied by the number of degrees its temperature was raised, divided by the number of minutes required for bringing the water to the boiling point, will give you the approximate amount of heat given off by the flame per minute.

If you make a number of tests as indicated above, the average of the results will give you a more accurate idea of the available heat given off by your flame per minute.

CHAPTER V

CHANGES IN THE STATE OF MATTER

Exercise 15. Change from a Solid to a Liquid.

Object: To determine the heat necessary to convert one gram of ice to water.

Apparatus

Cracked ice	Chemical thermometer
Balance and weights	Bunsen burner
Hot water	Tin beaker
Ring stand	Asbestos cover

Directions: Surround the tin beaker with the asbestos cover and ascertain the weight of both. Into the beaker pour 200 c.c. of water at 60 degrees C. Now obtain the weight of the beaker and water. Break 75 grams of ice into small pieces. After noting the exact temperature of the water in the beaker, wipe dry the pieces of ice and drop them into the water piece by

piece. When the ice is almost melted, note again the exact temperature of the water. Weigh again the beaker and its contents. Tabulate the data as follows:

1. Weight of beaker and cover.
2. Weight of hot water and beaker.
3. Weight of hot water (calculated).
4. Weight of beaker and water at end of experiment.
5. Weight of ice (calculated).
6. Temperature of water before ice was added.
7. Temperature of water after ice was melted.
8. Loss in temperature of water (calculated).
9. Increase in temperature of ice (calculated).

Multiply the weight of the hot water by its loss in temperature to obtain the number of calories required to melt the ice and raise it to the final temperature. Multiply the weight of the ice by its increase in temperature to obtain the number of calories used in raising its temperature. The difference between these results will give the number of calories used in melting the given amount of ice. How many calories are required to melt one gram of ice?

Why is the temperature of the atmosphere near a body of freezing water higher than the temperature of the atmosphere a little distance away?

Exercise 16. Solution.

Object: To show the effect of dissolving salt upon the temperature of water.

Apparatus

Beaker
Thermometer
Salt

Directions: Half fill a beaker with water. Carefully observe and record its temperature. Into the water put several teaspoonfuls of salt. Quickly insert the thermometer into the beaker. Do you note any changes in the temperature? What change is taking place in the salt? What is necessary to produce this change? For your answer refer to Exercise 15. Then how do you explain the change in temperature which occurs? Why is salt mixed with the ice in an ice cream freezer? When snow melts, what effect does this have on the surrounding temperature? Does this tend to increase or decrease the rate of melting? Of what advantage is this?

Exercise 17. Change from Liquid to Solid.

Object: To determine the effect on the temperature of a substance when it changes from a liquid to a solid.

Apparatus

Hypo
Flask
Thermometer
Cotton
Graduate
Bunsen burner
Wire gauze
Ring stand

Directions: Into the flask place 10 c.c. of water. To this add 50 g. of hypo. Slowly heat the flask until all of the hypo is dissolved. Close the mouth of the flask with some cotton and very carefully set it aside to cool. Take every precaution not to disturb

the flask while it is cooling. When it feels cool, remove the cotton, insert the thermometer into the liquid, and note the temperature. Shake the liquid until it begins to crystallize. As it does so, carefully observe the changes in temperature. Explain these results. What effect does a body of water which is freezing have upon the temperature of the surrounding atmosphere? Why?

Exercise 18. Change from a Liquid to a Gas.

Object: To determine the heat necessary to convert 1 c.c. of water into steam or water vapor.

Apparatus

Flask	Wire gauze
Thermometer	Bunsen burner
Asbestos cover for flask	Ring stand
Flame protector	Graduate, 100 c.c.

Directions: Set up apparatus as in Exercise 14. Obtain the heat of the flame as in that exercise. Continue to heat the water, noting the exact instant when it begins to boil. Allow it to boil for ten minutes. Turn off the gas and set the water aside to cool. After cooling, measure the water remaining in the flask.

Tabulate data as follows:

1. Amount of water at beginning.
2. Amount of water at end.
3. Loss in water (calculated).
4. Calories given off by flame per minute (calculated).
5. Length of time water boiled.

6. Number of calories used in boiling away water (calculated).

7. Number of calories required to boil away 1 c.c. of water (calculated).

8. Did the temperature rise during boiling?

9. What became of the heat?

Exercise 19. Effect of Pressure on Boiling Point.

Object: To show the effect of lowering the pressure on the boiling point of water.

Apparatus

Air pump	Wire gauze
Flask	Belljar
Thermometer	Vaseline
Bunsen burner	Rubber stopper
Ring stand	Beaker

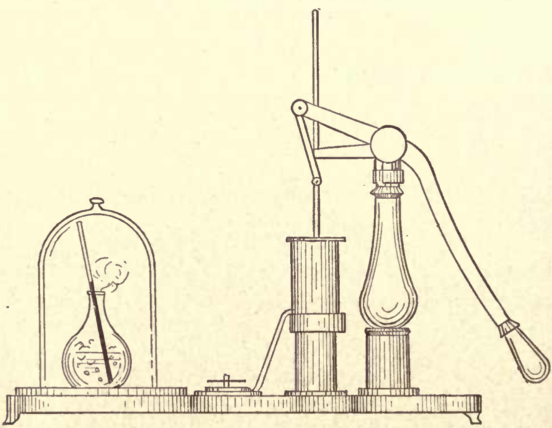


Fig. 15.

Directions: **A.** Half fill a flask with water and place it on a ring stand over the flame of a Bunsen burner.

Heat the water to about 60°C. Then remove the flask and place it on the receiver of the air pump. Rub the edge of the belljar with vaseline and then lower it over the flask. Exhaust the air from under the belljar. What happens to the water? What is the temperature at which water boils under ordinary conditions? How can you explain the results of this exercise?

If the belljar is sufficiently high, the thermometer should be left in the flask. Repeat the experiment several times, each time recording the temperature at which the water boils.

B. Again half fill the flask with water and heat it until it boils. After it has boiled about two minutes, insert the rubber stopper. Allow the flask to cool a few minutes and then invert it on the ring of the ring stand. Pour cold water over the flask. What happens to the water? Why? Will the boiling point of water be above or below 100°C. on top of a mountain? Why? It is impossible to cook potatoes by boiling on top of a very high mountain. Why?

Exercise 20. How Water is Distilled.

Object: To determine how substances dissolved in water may be separated from it.

Apparatus

Flask	Bunsen burner
One-hole rubber stopper	Ring stand
Delivery tube	Wire gauze
Test tube	Salt
Beaker	

Directions: Into a flask put about 200 c.c. of water and 3 or 4 teaspoonfuls of salt. Stir or shake the mixture until all the salt has dissolved. Then insert the delivery tube through the stopper and close the flask. Heat the solution to boiling. Put the free end of the tube into a test tube which is surrounded by cold water. Keep the water cold by adding ice or snow. Boil the water in the flask for about 5 minutes. Taste the liquid that has distilled over into the test tube. Is there any salt present? Of what commercial value is distillation?

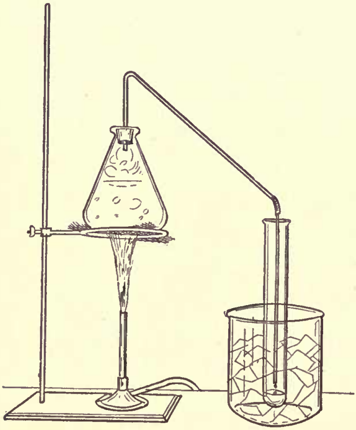


Fig. 16.

Exercise 21. Evaporation.

Object: To show a result of evaporation.

Apparatus

Thermometer	Absorbent cotton
Chloroform	

Directions: Wrap a small bit of cotton tightly about the bulb of a thermometer. Record the reading of the thermometer. Saturate the cotton with chloroform and wave the thermometer in the air to evaporate the chloroform. As it evaporates what change

in temperature do you note? How do you account for this change? See Exercise 18.

Water, ether, or alcohol may be used in place of the chloroform. Place a drop of chloroform on the back of the hand. What is the sensation produced as the chloroform evaporates? What is the principle used in the manufacture of ice by the use of ammonia?

CHAPTER VI

PHYSICAL AND CHEMICAL CHANGES

Exercise 22. Physical Change.

Object: To determine the nature of a physical change.

Apparatus

Salt
Distilled water
Evaporating dish
Wire gauze
Bunsen burner
Glass stirring rod
Ring stand

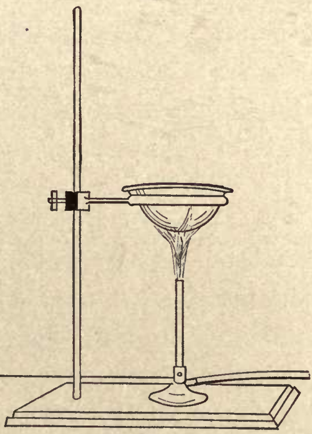


Fig. 17.

Directions: Place some salt in an evaporating dish. Cover it with distilled water. Stir it with the glass rod. What happens to the salt? Place the evaporating dish with the solution on the wire gauze over the flame. Heat the solution slowly until

all the liquid has evaporated, being careful not to burn the substance left in the dish. Taste the residue. What is it? Has its form changed? Its nature? Changes which do not involve a change in the composition of substances are called physical changes.

Exercise 23. Chemical Change.

Object: To determine the nature of a chemical change.

Apparatus

Sugar	Wire gauze
Sulphuric acid	Test tube
Evaporating dish	Potassium iodide crystals
Bunsen burner	Mercuric chloride crystals (poison)
Glass stirring rod	Mortar and pestle
Ring stand	

Directions: **A.** Cover some sugar in the evaporating dish with sulphuric acid. Stir the substance with the glass rod. What happens? Place the solution on the wire gauze and slowly heat it. What happens? Does the resulting substance resemble either the acid or the sugar with which you started?

Changes which involve a change in the composition of substances and result in the formation of new substances are called chemical changes.

Classify the following under the head of chemical or physical change respectively: A change from ice to water; water to ice; water to gas; gas to water; action of hydrochloric acid on marble as used in Exercise 6; burning of wood; cider to vinegar.

B. The following experiments are to be performed

by instructor only: Rub together in the mortar a few crystals of potassium iodide with a few of mercuric chloride. What evidence appears that a new substance is formed?

Dissolve a few crystals of potassium iodide in water in a test tube. In another dissolve about an equal quantity of mercuric chloride. Warm water will hasten solution. Pour a little of the potassium iodide solution into a third test tube, and gradually add mercuric chloride solution to it. The red precipitate is the same substance as was formed when the different kinds of crystals were rubbed together.

CHAPTER VII

CHEMICAL PHENOMENA

Exercise 24. Mechanical Mixture.

Object: To demonstrate a mechanical mixture.

Iron filings	Wire gauze
Salt	Ring stand
Magnet	Glass stirring rod
Beaker	Mortar and pestle
Evaporating dish	Funnel
Bunsen burner	Filter paper

Directions: Mix together in a mortar 2 grams of salt and 2 grams of iron filings. By means of a magnet, try to separate the iron from the salt. What is the result? Now pour the contents of the mortar into a beaker. Add 20 c.c. of water to the mixture, and with

a glass stirring rod, stir until the salt is all dissolved. Filter and evaporate the filtrate (the liquid which passed through the filter) to dryness, using the evaporating dish. What is the substance left in the evaporating dish? To determine this, taste it. With the magnet, test the substance left on the filter paper. What is it? In mixing together iron filings and salt were the properties of either changed?

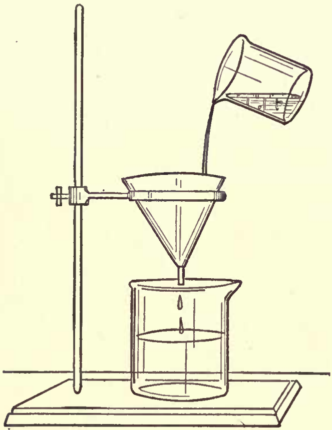


Fig. 18.

If two or more substances are placed together, and each retains its original properties, the resulting substance is called a mechanical mixture.

Exercise 25. Chemical Synthesis.

Object: To determine the formation of compounds.

Apparatus

Iron filings	Test tube holder
Flowers of sulphur	Bunsen burner
Test tube	Mortar and pestle
Magnet	

Directions: Note carefully the nature of the elements, iron filings and sulphur. Grind together in a mortar 2 grams of sulphur and 2 grams of iron filings. The grinding is to be done very thoroughly. With a

magnet try to separate the iron from the sulphur. What is the result? Place the mixture in a clean, dry test tube. With the test tube holder, hold the tube over the Bunsen flame until the contents begin to glow. Remove it from the flame until the glow ceases, then heat the tube again very strongly for a few minutes. Remove the tube from the flame. When cool, break the tube. Examine the contents. Test them with the magnet. What changes have the substances undergone? The new substance is a chemical compound called iron sulphide, resulting from the chemical union of the elements, iron and sulphur.

Another experiment to show chemical synthesis is to grind together in a mortar, mercury and iodine crystals.

Exercise 26. Chemical Analysis.

Object: The decomposition of compounds.

Apparatus

Mercuric oxide	Pine splinter
Hard glass test tube	Bunsen burner
Test tube holder	

Directions: Such characteristics as hardness, color, form, etc., are known as the physical properties of a substance.

Note carefully the physical properties of mercuric oxide. Place a very small amount of it in a test tube and heat it very thoroughly. With the test tube in the flame, insert a glowing pine splinter into the tube. Continue heating the mercuric oxide. What change

do you note in the ember? Where does the substance come from that causes this change? This same substance is found in the air and is called oxygen.

Examine the sides of the tube a little above the mercuric oxide. What do you find there? From what substance did it come? Scrape it from the sides of the tube and shake it out on to a piece of paper. Thus mercuric oxide has been separated by means of heat into its elements, oxygen and mercury. The process of separating or decomposing a compound into its elements is known as chemical analysis.

CHAPTER VIII

CHEMICAL ELEMENTS

Exercise 27. Carbon.

Object: To determine some of the properties of carbon.

Apparatus

Wood charcoal	Pine splinter
Lime water	Crushed marble
Test tube	Dilute hydrochloric acid
Beaker	

Directions: One of the forms in which carbon occurs is charcoal. Examine a stick of wood charcoal. What is the color? Is it soluble in water? Light the stick of charcoal. Does it burn freely? Does it give off any odor in burning? Thrust the lighted charcoal into the mouth of a test tube containing some clear lime water.

Allow it to burn in the tube for a minute, then remove it and mix the lime water with the gas in the tube by shaking. What is the effect of the gas on the lime water? Then what must this gas be? (See Exercise 6.)

Rinse the test tube with water. Again place some lime water in it. Light the pine splinter and thrust it into the test tube. Remove the splinter and shake the lime water. What change do you note in the lime water? Does wood contain carbon?

Place a few pieces of marble in a clean test tube. Pour on it a little dilute hydrochloric acid. What happens? This is a chemical action between the marble and the acid. Over the mouth of this test tube place the mouth of another to collect some of the gas given off. Remove the second test tube, pour into it some lime water and shake. What is the effect on the lime water? What does this indicate? Hydrochloric acid contains no carbon. Does marble?

What are the properties of carbon as found in charcoal? In what substances did you find carbon? What other forms of carbon do you know?

Exercise 28. Phosphorus. (Demonstration.)

Object: To determine some of the properties of phosphorus.

Apparatus

Yellow phosphorus	Forceps
Red phosphorus	Knife
Evaporating dish	Filter paper

Directions: (CAUTION—Yellow phosphorus must be

kept under water and cut under water. It must not be allowed to come in contact with the bare skin.)

With the forceps place a small piece of yellow phosphorus in the evaporating dish, which has been filled with water. Cut off a piece with the knife. Does it cut easily? What is the appearance of the new cut surface? What is the consistency of phosphorus? Pick up a small piece with the forceps and hold it in the air a moment. What takes place? Does phosphorus give off an odor in burning? Why is it kept under water? Rub phosphorus on a piece of filter paper and examine the paper in the dark room. What do you see? Will phosphorus burn at a low temperature?

Place a small piece of freshly cut phosphorus in a dish of water exposed to the light. Cover with a bell jar and leave for at least 48 hours. Does any change in color occur? Examine a small quantity of red phosphorus. Compare in all details its properties with those of yellow phosphorus. What is the difference between an ordinary and a safety match?

Exercise 29. Sulphur.

Object: To determine some of the properties of sulphur.

Apparatus

Flowers of sulphur	Beaker
Deflagrating spoons	Silver spoon
Roll sulphur	Bunsen burner
Test tube	Test tube holder

Directions: Examine a little of the flowers of sul-

phur. What is its nature? Color? Has it any odor? Taste? Place some of it in a small beaker and cover with water. Does it dissolve?

With a very low flame slowly heat a little sulphur in a test tube. What change takes place? What is its color? Continue to heat slowly and watch very carefully the change in consistency and color. When the substance thickens and turns a darker color, continue to heat it until it becomes a thin liquid and then pour part of it into a beaker of cold water. Immediately work the substance in the water with the fingers. What is its nature? Is it elastic?

Continue to heat the sulphur in the test tube. What collects on the sides of the tube? What is it? Place a little sulphur in the deflagrating spoon and ignite it. Does it burn easily? What is the color of the flame? Do the fumes have an odor? When sulphur burns it forms a gas called oxide of sulphur, or sulphur dioxide. Examine some roll sulphur. How does it differ from the flowers of sulphur?

Place some sulphur in the bowl of a silver spoon or on a silver coin. Heat it slightly. What is the effect of sulphur on silver? The compound formed is called sulphide of silver.

Enumerate the properties of sulphur you have learned.

Exercise 30. Iron.

Object: To determine some of the properties of iron.

Apparatus

Iron wool
Iron filings
Magnet
Beaker
Oxalic acid
Acid potassium oxalate
Acetic acid
Ammonium hydroxide
Sulphuric acid

Directions: A. Place some of the iron filings on a piece of paper. Slowly bring the magnet in contact with the filings. Raise the magnet. Are there filings attached to it? Are other things attracted to it in the same way? To answer this question try the magnet on a silver coin, a penny, a pin, a piece of gold, etc.

Moisten some iron wool and set it aside in a beaker for forty-eight hours. What is the appearance of the iron wool at the end of that time?

Do you know what this reddish deposit is? This is a compound which iron forms with the oxygen of the air in the presence of moisture. From your general observations what other properties of iron could you add to this list?

B. Linen, cotton, and other textiles frequently become soiled with such a reddish deposit, and a "rust stain" results. Being insoluble in water and alkalies, such stains are not removed by the ordinary washing processes. However, rust or iron oxide is converted to a soluble salt by the action of suitable acids.

Stain several pieces of white cotton cloth with iron rust. This may be done by placing moistened iron filings on the cloth and leaving them for about thirty

minutes. Treat each separately with one of the following:

1. Dilute sulphuric acid.

2. Dilute sulphuric acid, then wash and neutralize with weak ammonium hydroxide.

3. Dilute acetic acid; wash, etc., as in 2.

4. Oxalic acid, dissolved in hot water; wash, etc.

5. Acid potassium oxalate, dissolved in hot water; wash, etc.

Which is the most rapid and effective in action? Examine specimens number one and number two after several days have elapsed. Has the acid attacked the cotton as well as dissolved the stain? Why should the cloth always be thoroughly washed after treatment? What is the added advantage of using ammonia water?

Exercise 31. Oxygen.

Object: To determine some of the properties of oxygen.

Apparatus

Potassium chlorate	Bunsen burner
Manganese dioxide	Large mouth bottles
Florence flask	Glass plates
Rubber stopper (one-hole)	Deflagrating spoon
Pneumatic trough	Charcoal
Delivery tube	Sulphur
Ring stand	Pine splinter
Wire gauze	Lime water

Directions: Place in the flask a mixture of four parts of potassium chlorate and one part of manganese dioxide. Insert into the mouth of the flask the rubber

stopper carrying the delivery tube. Place the free end of the tube in the pneumatic trough. Place the flask on the wire gauze over the flame of a Bunsen

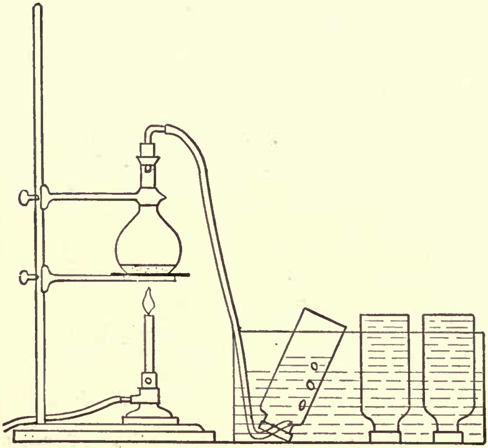


Fig. 19.

burner and heat gently. By heating the mixture a gas, called oxygen, is given off. Allow the first gas from the flask to escape. Why? Then place the delivery tube under the mouth of an inverted bottle filled with water. When the bottle is filled with oxygen, cover it with a glass plate and set it aside. Fill five other bottles with oxygen in the same manner.

1. Examine the gas in one bottle. Has it any color? Any odor?

2. Place a piece of charcoal in the deflagrating spoon and heat it until it glows. Quickly thrust it into a bottle of oxygen. Note the result. What property does this show oxygen to possess? What are the

fumes given off from the burning charcoal? To determine this pour some lime water into the bottle and shake.

3. Into the deflagrating spoon place some powdered sulphur. Light the sulphur and lower it into a bottle of oxygen. What is the result? After the sulphur has burned, smell the fumes in the bottle. What are they? How were they formed?

4. Burn a pine splinter until a good ember is formed. Extinguish the flame and thrust the glowing ember into a bottle of oxygen. What happens?

Does oxygen burn? Does it support combustion? Is it found in the air? Why do you think it is or is not found in the air?

Summarize the properties of oxygen you have learned from this exercise.

Exercise 32. Hydrogen.

Object: To determine some of the properties of hydrogen.

Apparatus

Granulated zinc
Dilute hydrochloric acid
Flask
Test tubes
Thistle tube
Delivery tube
Pneumatic trough
Pine splinter
Large mouth bottles

Directions: Place a handful of zinc in the flask. Into the mouth of the flask insert a rubber stopper, fitted with the thistle tube and the delivery tube. Pour enough hydrochloric acid through the thistle tube into

the flask to cover the zinc. What action is observed? This is a chemical action between the zinc and the

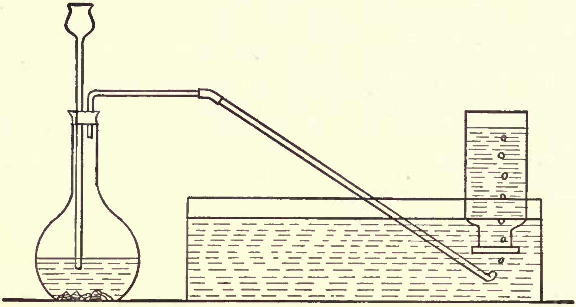


Fig. 20.

acid. The gas given off is hydrogen. Allow the gas to escape from the delivery tube for a few seconds. Why? Fill a number of bottles with hydrogen by the downward displacement of water. Keep the bottles inverted.

1. Examine the hydrogen in one of the bottles. Has it any color? Odor?

2. With the mouth downward, thrust into a second bottle of hydrogen a lighted splinter. What is the result? Does the splinter continue to burn? Does the hydrogen burn? If so, what is the color of the flame? Examine the sides of the bottle? What do you find there? Where did it come from? What is the oxide of hydrogen?

3. Allow a third bottle of hydrogen to stand mouth upward for three minutes. Then insert a lighted splinter. Is the hydrogen still there? Is hydrogen lighter or heavier than air?

Exercise 33. Nitrogen.

Object: To determine some of the properties of nitrogen.

Apparatus

Ammonium chloride	Bunsen burner
Sodium nitrite	Wire gauze
Flask	Wide mouth bottles
Rubber stopper	Glass plates
Delivery tube	Pine splinter
Pneumatic trough	Thistle tube
Ring stand	

Directions: Place 8 grams of sodium nitrite, 3 grams of ammonium chloride, and 15 c.c. of water in the flask. Into the mouth of the flask insert a rubber stopper, fitted with a thistle tube and a delivery tube. Place the flask on the wire gauze over the Bunsen flame. Heat gently and allow the first gas to escape. Fill several bottles with water, and invert them in the water in the pneumatic trough. Fill the bottles with the gas from the flask by downward displacement of water. The gas given off is nitrogen. Examine a bottle of nitrogen. Has it color? Odor?

Into a second bottle of nitrogen insert a lighted splinter. Does the splinter continue to burn? Does the nitrogen burn?

What are the properties of nitrogen?

CHAPTER IX

ACIDS, BASES, AND NEUTRAL SUBSTANCES

Exercise 34. Acids and Bases.

Object: To determine the properties of acids and bases.

Apparatus

Hydrochloric acid (dilute)	Red litmus paper
Nitric acid (dilute)	Blue litmus paper
Sodium hydroxide	Glass rod
Ammonium hydroxide	Beaker

Directions: Examine some of the dilute hydrochloric acid. Describe its odor. Dip the glass rod into the acid and touch it to the tip of the tongue. What is its taste? Rub some acid between the fingers. Describe its "feel." Dip a piece of red litmus paper into the acid. What is the effect of the acid on the paper? Dip a piece of the blue litmus into the acid. What effect does the acid have on the blue paper?

Apply the above tests to the nitric acid. Are the results the same as those obtained with the hydrochloric acid? These are methods commonly used to detect any acid.

Examine some sodium hydroxide. Describe its odor, taste, "feel," using the methods given in the study of acids. Test this substance with both red and blue litmus paper. What are the results? Examine ammonium hydroxide in the same manner. How do the results compare with those obtained with sodium

hydroxide? These substances are called bases. All bases react similarly to these tests.

Exercise 35. Salts and Neutralization.

Object: A study of neutralization and its results.

Apparatus

Hydrochoric acid (10%)	Blue litmus paper
Sodium hydroxide (10%)	Glass rod
Evaporating dish	Bunsen burner
Red litmus paper	

Directions: Pour one cubic centimeter of hydrochloric acid into the evaporating dish. To this add, drop by drop, some sodium hydroxide. Stir constantly to mix the liquids. Test the solution frequently with both kinds of litmus paper. If too much sodium hydroxide is added, the solution will turn the red litmus paper blue; if too much acid is present, the blue litmus will turn red. Balance the solution by alternately adding a few drops of acid and base until neither litmus paper is affected. When a solution has no effect on either red or blue litmus paper, it is said to be neutral. The process of mixing an acid and base to produce a neutral substance is called neutralization.

Over a flame evaporate the solution. Examine the residue. What is its appearance? Does it taste like any substance with which you are familiar? This product is called a neutral salt. Dissolve some of it in water. Does the solution have any effect on litmus paper? What was the substance evaporated? What, then, are the products of neutralization?

CHAPTER X

WATER AND AIR

Exercise 36. A Simple Electric Cell.*

Object: To show how a current of electricity is produced.

Apparatus

Strip of amalgamated zinc, 4x1
(Strip of copper 4x1)
Two pieces of copper wire, each 12 in. long
A block of wood about 4x1x1
Dilute sulphuric acid, about 5%.
A compass or magnetic needle

Note: On one side, at the mid-point of the long axis of the block of wood, tack the strip of zinc perpendicularly with one inch of the zinc projecting above the wood and two inches extending below. On the opposite side of the wood, similarly fasten the strip of copper. To the upper ends of the metallic strips attach the copper wires.

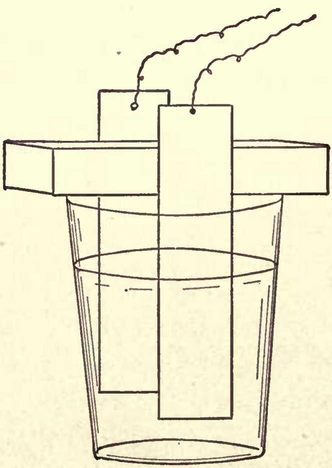


Fig. 21.

Directions: Fill the glass about $\frac{2}{3}$ full of the

*This exercise is given here for those teachers who wish to present to their classes some preliminary facts about electricity before performing Exercise 37.

sulphuric acid solution. Put the block of wood across the tumbler with the free ends of the metals dipping into the acid. Record what happens. Are there any bubbles of gas given off? From where do they come? Touch the free ends of the copper wires to your tongue. What effect do you notice? What is the evidence that an electric current is passing through the wires? Twist the free ends of the wires together and hold them over the compass. How is the compass affected? Is there evidence of an electric current? Record all of your observations. Find out from some source what is the origin of the electric current.

Exercise 37. Composition of Water. (Demonstration.)

Object: To determine the composition of water.

Apparatus

Electrolysis apparatus	Pine splinters
Sulphuric acid (5%)	Belljar
Electric current	

Directions: Fill the apparatus with water containing 5% sulphuric acid. When the apparatus is almost filled, into each arm insert the burette, at the same time opening the cock to drive out the air. After the burettes are completely filled, connect the positive and negative poles of the series with the city current. Note what happens. From what place do the bubbles arise? In which tube do they form more rapidly?

What is the ratio by volume of the gases in the

two tubes? This may be accurately obtained by taking the readings on the burettes. When the tube containing the most gas is three-fourths full, disconnect the current. Remove the entire apparatus into a trough of water, so that the open ends of the arms are submerged. Then remove each burette separately, the one of less volume first. Cover the mouth of the burette with the finger and invert. Remove the finger and quickly insert a lighted splinter into this gas. What happens? What is this gas?

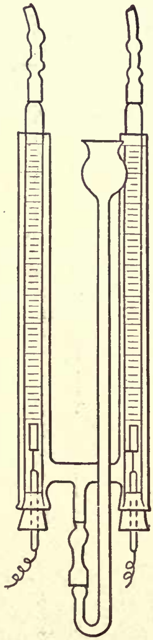


Fig. 22.

Remove the other burette in the same manner as the first. Hold the mouth downward and insert a lighted splinter. What happens? What is this gas? (See Exercise 32.)

Of what elements is water composed? What proportion by volume?

Exercise 38. Composition of Air.

Object: To determine the composition of air.

Apparatus

Pneumatic trough	Beaker
Belljar	Glass plate
Evaporating dish	Pine splinter
Phosphorus	Test tube
Lime water	Iron filings

Directions: **A.** Fill the beaker with lime water and

leave it exposed to the air for 48 hours. At the end of that time examine the appearance of the surface of the water. What does this indicate? What then forms a part of the air?

Does wood burn in the air? What element does this indicate to be present? How does the burning of a pine splinter in the air compare with the burning in Exercise 31, part 4? What does this indicate?

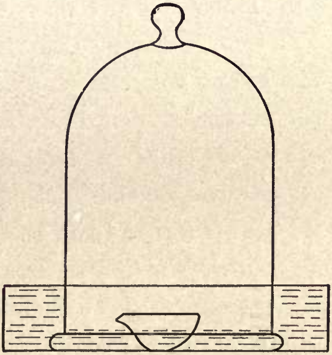


Fig. 23.

Pour water, of room temperature, into the pneumatic trough. On the surface of the water float the evaporating dish containing a piece of phosphorus, the size of a small pea. Ignite the phorphorus and cover quickly with the bell jar. What is the result? With what does the phosphorus unite in burning? When does it stop burning in the jar? What are the white fumes? Leave the experiment until these fumes have been dissolved in the water. Does the water rise in the jar? What part by volume does it occupy? This represents the approximate proportion of oxygen in the air.

Slip a glass plate over the mouth of the belljar and invert it. Examine the gas. Has it color? Odor? Will it support combustion? Does it burn? What is this gas? (See Exercise 33.) Air is a mixture of gases of

which the above are the chief ones. If this experiment is performed at home, a small candle may be lighted under the belljar instead of phosphorus.

B. In a test tube place about a half teaspoonful of iron filings. Cover them with water. Then invert the test tube and allow the water to run out slowly so that the filings will adhere to the sides of the tube. Place the mouth of the tube in a beaker filled with water and allow the apparatus to stand for twenty-four hours. At the end of that time measure the height to which the water has risen in the tube. What part of the air by volume did the oxygen occupy? What change has taken place in the iron filings? How do the results in this experiment compare with those in the one above?

CHAPTER XI

ATMOSPHERE

Exercise 39. Does Air Exert Pressure? (Demonstration.)

Object: To demonstrate air pressure.

Apparatus

Oil can with screw top	Bunsen burner
Magdeburg hemispheres	Water
Air pump	

Directions: A. Screw the Magdeburg hemispheres on to the plate of the air pump and open the stop-cock. Exhaust the air from the hemispheres and close the

stop-cock. Try to separate the hemispheres. What do you find? Open the stop-cock and try to separate the hemispheres. How does this result compare with the result obtained in the first instance? How do you explain these results?

B. Fill the tin can with water to a depth of two inches. With the aperture open, place the apparatus over the Bunsen flame and heat until the water boils. Tightly close the aperture and remove the apparatus. Let it cool and note what happens. How do you explain the result?

Exercise 40. Barometer. (Demonstration.)

Object: To study a means of measuring atmospheric pressure.

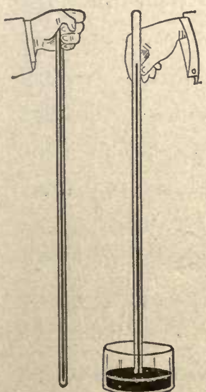


Fig. 24.

Apparatus

Mercury	Barometer
Glass dish	Meter stick
Torricellian tube	

Directions: Fill the Torricellian tube with mercury. Carefully close the open end with the thumb and invert the tube into a basin of mercury. Remove the thumb from the open end of the tube under the mercury in the basin. Measure the height of the column of mercury in the tube above the surface of the mercury in the basin. What keeps the mercury in the tube? Would the same results be obtained if both ends of the tube were open?

Examine the standard barometer. How does the height of the column of mercury in the tube compare with that of the barometer? The principle upon which each is constructed is essentially the same. The barometer is an instrument used for measuring atmospheric pressure.

Exercise 41. Siphon.

Object: To demonstrate the action of a siphon.

Apparatus

Rubber tubing	Battery jars

Directions: Fill a battery jar with water and place it on top of the desk. Immerse a piece of rubber tubing about 3 feet long into the jar of water. When the tube is filled with water, close one end of the tube by pinching between the fingers. Place a second battery jar on a chair or on the floor below, but near, the first jar. Quickly remove the closed end of the rubber tube and put it into the lower vessel. Release the tube. What happens? What caused the water to run? How long does the water run? What causes the water to rise in the first part of the tube? What pulls it down into the longer arm?

Instead of immersing the rubber tube in water to fill it, place one end in the jar of water. Then suck the air out of the tube until it is filled with water. Then remove the mouth and note the result.

Can you suggest any uses for the siphon?

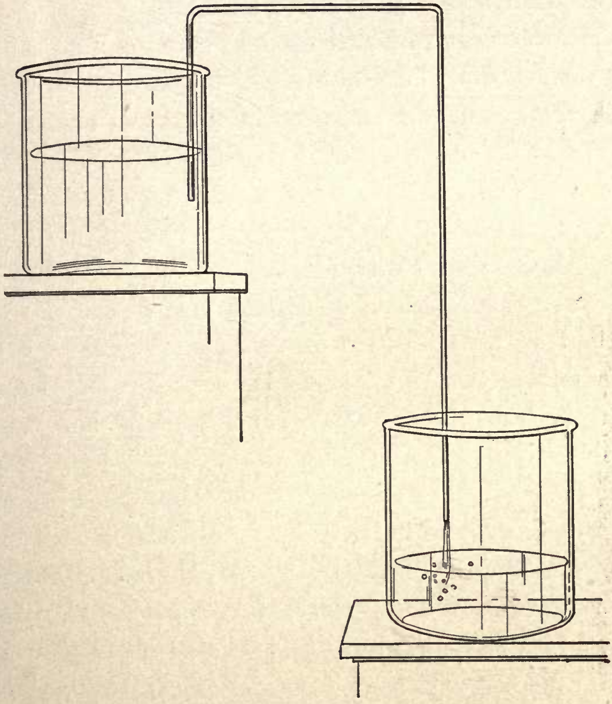


Fig. 25.

Exercise 42. Convection.

Object: To show a method of producing currents in air and water.

Apparatus

Bunsen burner
Wire gauze
Cotton, dandelion, or milk-weed fruits
Ring stand
Test tube
Water
Test tube holder
Fine sawdust

Directions: A. Convection of Gases.

Place the wire gauze on the ring stand and adjust a low flame under the gauze. Over the wire gauze drop very small bits of cotton or the fruits of dandelion or milk-weed. Make a drawing indicating with arrows the path taken by the moving particles. How do you explain this action?

B. Convection of Liquids.

Place a small amount of fine sawdust in the bottom of the test tube. Fill the test tube three-quarters full of water. Adjust the Bunsen burner for a low flame. Hold the test tube at a small angle over the flame and heat it gently at one point at the base. Note very carefully the movements of the sawdust particles as the water becomes heated. Make a drawing, indicating with arrows the direction taken by the particles in the water. How do you explain these movements? How does this result compare with that obtained with gas?

Convection is the process by means of which heat is carried from a hotter to a colder substance by a moving fluid.

Crystals of potassium permanganate may be used effectively in place of sawdust to show convection currents in liquids.

Exercise 43. Moisture in the Atmosphere—Condensation.

Object: To show the presence of water-vapor in the atmosphere.

Apparatus

Beaker
Ice
Flask
Glass plate
Bunsen burner

Directions: A. Fill the beaker with small pieces of ice and water. Dry the surface of the beaker thoroughly and set it aside for about five minutes. At the end of that time what do you find on the surface of the beaker? How do you account for it?

B. Fill the flask half full of water and place it over the Bunsen flame. Heat the water until it boils. Hold a dry glass plate over the mouth of the flask. What do you find on the plate? What is its source? Why did you use the glass plate? What happens when the temperature of the atmosphere is suddenly lowered?

Exercise 44. Study of the Weather Map.

Object: To study the causes of weather changes.

Apparatus

Several weather maps for each pupil. These maps should include some with well developed *low* regions and some with well developed *high* areas.

Directions: At the lower left corner of the map are "Explanatory notes." Read them. At the lower right corner of the map is the "Wind-barometer indication." Study this.

Locate the isothermal and isobaric lines. What does each mean? All barometric readings have been reduced to what they would be if the place were at sea level.

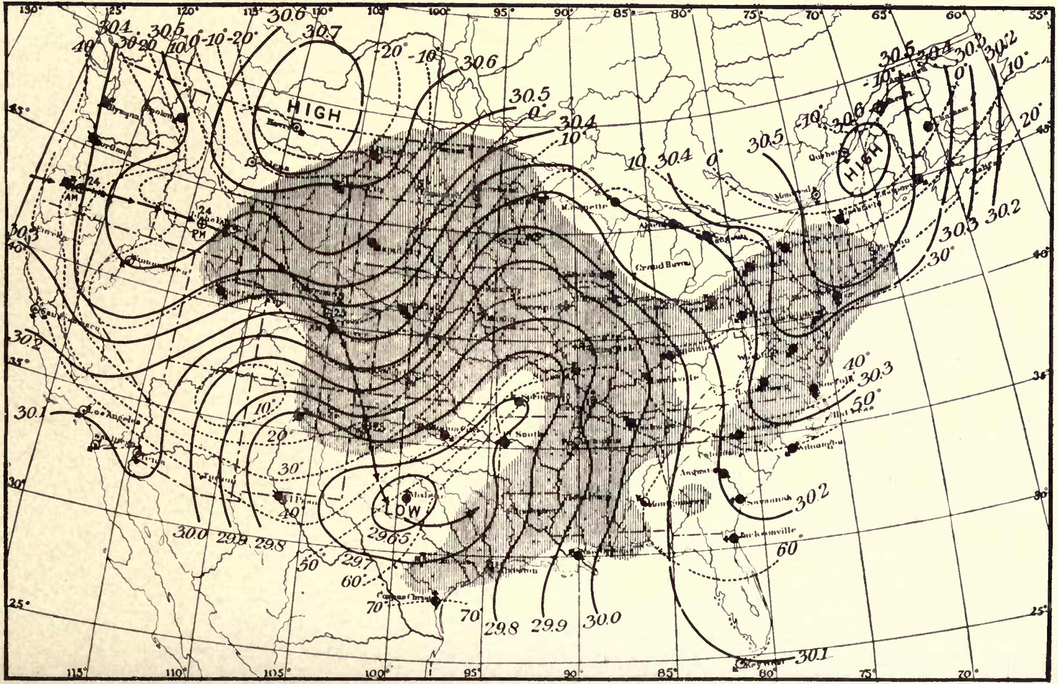
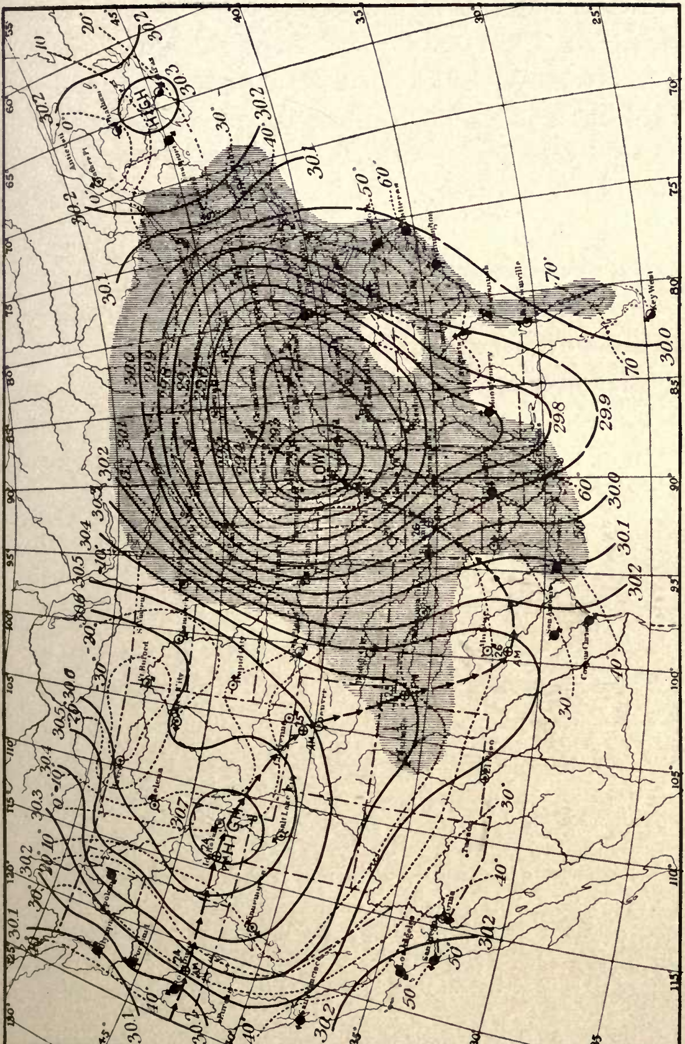


Fig. 26. Weather map, December 26, 1904. Continuous lines are isobars; dotted lines are isotherms; arrows fly with the wind; shaded area shows precipitation of .01 inch or more; circles indicate state of weather: ○ clear; ◐ partly cloudy; ● cloudy.



Maps from Chicago Weather Bureau.

Fig. 27. Weather map, December 27, 1904. Symbols are the same as in the preceding map.

Select a map with a well developed low region. This low region is called a cyclone or cyclonic area. Using the scale of miles indicated on the map, find the approximate width of this low region. How many states does it cover? Can you tell in what direction it is moving? What is the air pressure (barometric reading) at the center of the low area? How much would the barometer rise in being carried from the center of the low to the outer isobar of the area? What is the weather condition over the low region? Study the direction of the wind over the whole low area. To what conclusion do you come as regards the direction of the wind in the low region? About what is the average wind velocity of this area?

Select another map with a well developed high area, having a number of isobars curving around the word high. This region is called an anticyclone or anticyclonic area. What is the air pressure at the center of this high area? How much would a barometer fall in being taken from the center of this high to the center of an adjacent low area? What is the weather condition over the high area? Study the direction of the wind over the high region. What is the difference between the general direction of the wind over the high and low regions?

What is the general direction of the movement of the high and low areas? Find out from some source how rapidly they move. Study the isothermal lines. What is their general direction? What is the lowest and

highest temperature recorded on the map? What relation does temperature have to the high and low area regions?

Choose a map, give its date, and record for your locality, the temperature, direction of the wind, velocity of the wind, barometer reading, state of the sky, and kind of precipitation, if any.

CHAPTER XII

SOILS

Exercise 45. Water Capacity of Soils.

Object: To determine the capacity for water of different soils.

Apparatus

Sand	Leaf-mold
Clay	Tin cans
Loam	Balance and weights

Directions: Expose the different soils used in this exercise to the room air for a period of two days. At the end of that time find the weight of the can. The can should have a number of holes in the bottom. Fill the can two thirds full of the air dried sand, and find the weight of both the can and the sand. Then compute the weight of the sand. Thoroughly saturate the sand with water and set it aside for about two hours. Again weigh the can with its contents. From this result subtract the weight of the can and dry soil. The difference represents the amount of water,

by weight, which the sand is capable of holding. What per cent of the weight of the sand is the weight of the water?

Repeat the above experiment for each of the soils: clay, loam, and leaf-mold, or any combination of soils suggested by the instructor.

Is the water capacity the same for all soils? Which holds the most? Which the least?

Record results as follows:

	Sand	Clay	Loam	Leaf-mold	Sand and Leaf-mold	Clay and Leaf-mold
Weight of can						
Weight of can and dried soil						
Weight of dry soil (calculated)						
Weight of both with water						
Weight of water (calculated)						
Water capacity in per cent.						

Exercise 46. Soil Solutions.

Object: To determine whether water in passing through the soil dissolves mineral substances.

Apparatus

Evaporating dishes
Bunsen burner
Well water
Rain water
Slips of Wandering Jew
Flasks
Ring stand

Directions: **A.** Place 50 c.c. of well water in one evaporating dish and the same amount of rain water,

or distilled water, in another. Evaporate the water in each dish over the Bunsen flame. What is left in each case? How do you account for the difference?

B. In which kind of water do plants grow best?

Fill one flask with well water and another with rain, or distilled water. In each flask place "slips" of Wandering Jew of about the same size. Change the water in the flasks two or three times a week for about a month. In which do the plants grow best? What is the explanation?

CHAPTER XIII

PLANTS DEPENDENT UPON AIR AND MOISTURE

Exercise 47. Gross Structure of Leaves.

Object: To study the parts of a leaf.

Apparatus

Lilac leaves	Lily-of-the-valley leaves

Directions: A. Parts.

Carefully examine a lilac leaf. Make a drawing of the leaf. Label the broad expanded portion, the *blade*, and the stem by which it was attached, the *petiole*. Compare the lengths of the petioles on a number of leaves on a lilac branch. From this observation what is one of the functions of the petiole? The surface of the leaf is provided with small openings or pores, called *stomates*, through which the leaf respires.

At the discretion of the instructor these may be shown under the microscope.

B. Venation.

Examine the lilac leaf again. Note the continuation of the petiole through the blade. This is called the *mid-rib,* and its branches, the *veins.* Compare the arrangement of the veins in the leaves of any lily with that of the lilac leaf. How do they differ? These are examples of the two kinds of venation. Make a drawing of each and label the lilac leaf, *netted veined,* and the lily leaf, *parallel veined.*

Exercise 48. Chloroplasts.

Object: To study the organs which contain the green coloring matter of plants.

Apparatus

Moss or Elodea leaves	Scalpel
Glass slides	Compound microscope
Cover glasses	

Directions: Place a drop of water on the center of a glass slide. In this put a leaf of elodea or moss and cover it with the thin glass cover. Examine this very carefully under the low power of the microscope. Note the oblong parts of which the leaf is composed. Each of these parts is a *cell.* Examine one of these carefully. What is its shape? What is the appearance of the wall, *cell wall,* surrounding it? Within the cell note the many small bodies, green in color. What is their shape? How many are there in a

cell? What is their arrangement? These small bodies contain a green substance known as *chlorophyll* and for that reason they are called *chloroplasts* (*chloro* means green; *plattein,* to form). Within the cell there is an almost colorless, jelly-like substance known as *protoplasm.* This is the living part of the cell. It is somewhat granular in appearance. Upon careful examination you may be able to see it.

Exercise 49. Making of Food for Plants.

Object: The relation of chlorophyll to starch formation.

Apparatus

Variegated geranium	Iodine
Alcohol	Beaker
Bunsen burner	Evaporating dish
Corn starch	

Directions: Place a small amount of corn starch in an evaporating dish and pour a drop of iodine over it. What color does the starch turn? If, when iodine is placed on a substance, its color turns to a blue-black, starch is present.

Place a geranium with variegated colored leaves in the bright sunlight for the greater portion of a day. Select a few leaves on the plant and sketch the blades to show the color patterns on them. Remove these leaves and immerse them immediately into boiling water to kill them. After five minutes boiling, place the leaves in a vessel of 96% alcohol to extract the chlorophyll. When the leaves become white, spread

them on a white surface and cover them with a weak solution of iodine. In what part of the leaf is starch found? Has chlorophyll anything to do with starch formation?

Exercise 50. Making of Food for Plants, continued.

Object: To determine the relation of sunlight to starch formation.

Apparatus

Nasturtium	Iodine
Alcohol	Beaker
Bunsen burner	Evaporating dish
Corn starch	

Directions: Place a nasturtium plant in the bright sunlight and another in a dark room. On the afternoon of the second day remove several leaves from each plant, being careful to keep the two sets of leaves separate. Kill them and extract the chlorophyll in the same manner as directed in the preceding exercise. Place the leaves on a white surface and test each for the presence of starch. Is starch found in both sets of leaves? What does this indicate concerning the relation of sunlight to starch making?

Exercise 51. By-Products in Food Making.

Object: To determine the gas given off when plants make starch.

Apparatus

Green water plants	Funnel
Mushrooms	Test tube
Glass jar	Pine splinter

Directions: Place some green water plants under a funnel in clear water, as in Figure 28. Place the jar in sunlight for several days, and allow any escaping gas to collect in a test tube placed over the stem end of the funnel. When there is an inch or more of gas in the test tube, remove the tube from over the funnel, being careful not to take it out of the water in the jar. After closing the mouth of the tube with the thumb, remove it from the jar of water. Invert the tube, then remove the thumb and quickly thrust a glowing pine splinter into the gas in the tube. What is the result? What gas does this indicate is present?

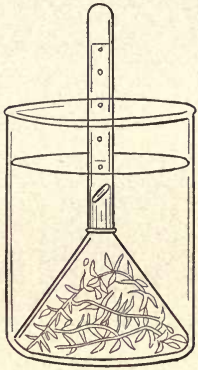


Fig. 28.

Repeat the same experiment, using mushrooms in place of the green plants. What result do you obtain this time? How do you account for the difference between this result and the one obtained with the green plants?

Exercise 52. Transpiration.

Object: To show that the excess water in plants is given off by the leaves.

Apparatus

Glass tumblers	Paraffin
Card board	Geranium

Directions: Cut off a small branch of geranium. Place the cut end of it through a hole in a piece of

cardboard. Fill one tumbler with water and place the cardboard over it, with the cut end of the geranium

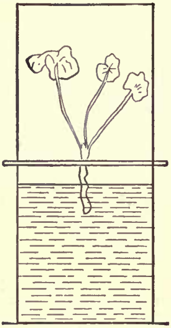


Fig. 29.

extending into the water. Paraffin the entire upper surface of the cardboard to prevent any evaporation of water through it or around the stem of the geranium. Over the leaves of the geranium invert the second tumbler and set the experiment aside for a few hours. Then examine the inside of the upper tumbler. How do you account for the condition found?

Exercise 53. Rate of Transpiration.

Object: To determine the difference in the rates of loss of water in different plants.

Apparatus

Cobalt paper	Scissors
Rubber plant	Paper clips
Nasturtium	

Directions: Cobalt paper is prepared by saturating filter paper in a solution of cobalt chloride. The paper is then thoroughly dried in an oven. What is the color of the paper? On a small piece of paper place a drop of water. What happens? Cut several pieces of paper, each about one inch square. With a clip fasten one piece on the upper, and another piece on the under surface of a leaf of a rubber plant. Note the exact time that this is done. Watch the paper. What change do you observe? How long did it take to produce this

change? What causes it? Do the papers on the upper and lower surfaces change at the same time? What does this indicate? Repeat this experiment on leaves of the nasturtium and of several other plants. At what rate do you find water is given off from their leaves? Do all plants transpire at the same rate?

Exercise 54. Is Air Necessary?

Object: To determine whether air is necessary for the growth of plants.

Apparatus

Wide mouth bottles	Paraffin
Rubber stoppers	Glass plate
Seeds (well soaked)	Belljar
Geranium plant	Blotting paper

Directions: A. Place blotting paper to the depth of an inch in the bottom of each of two wide mouth bottles. Saturate the paper thoroughly with water. Fill each bottle three-fourths full of soaked pea seeds. Close one bottle tightly with a rubber stopper to exclude the air and leave the second bottle open to the air. Place the two bottles under the same conditions of temperature and light. Make and record daily observations for one week on the growth of the seeds in the bottles. What do you conclude from the results?

B. Do other forms of plant life require air? To determine this select two potted plants of equal size. Water both plants thoroughly and place one under a belljar. Make this air-tight by sealing the open end of the belljar to a glass plate. Now place the

two plants under the same conditions of light, moisture, and temperature. Do not change these conditions until the experiment is completed.

Note and record results as you did with the seeds. At the end of a week do you notice any differences in the two plants? What does this indicate?

Exercise 55. Exchange of Gases in Respiration.

Object: To determine the gases exchanged in respiration of plants.

Apparatus

Wide mouth bottles	Pine splinter
Green plants	Stoppers
Lime water	

Directions: Fill three bottles to the depth of one-half inch with water. Into two of the bottles place a few shoots of green plants. Close the three bottles tightly with rubber stoppers and place them in a dark room until the next recitation. What gas was in the bottles when the experiment was set up? Is this same gas present in the bottles containing the green plants at the end of the experiment? In the bottle without plants? To determine this, insert into one of the bottles with plants a lighted splinter. What is the result? In the same manner insert a lighted splinter into the bottle having no plants. What is the result? What do these results indicate? Test the gas in the third bottle with lime water. What is the effect? From these results what gases are exchanged in respiration of plants?

Exercise 56. Roots.

Object: A study of the kinds and functions of roots.

Apparatus

Lupine seedlings	Carrot
Wheat seedlings	Dahlia roots

Directions: Examine the root of a lupine. Is there a single branch, or are there several of equal size arising from the same point? These are called the *primary roots.* The roots growing from the primary are called the *secondary roots.* Have they any definite arrangement on the single primary root of the lupine? At what angle do they grow from the main root? What function of the root does this suggest? With the lupine compare a carrot, radish, beet, or dandelion root. How do the latter differ from the lupine? What other function does this suggest for some roots?

Examine the roots of some grain seedlings. Do they have a single primary root or many *fibrous roots?* Make observations similar to those made on the lupine root. What difference do you observe? Compare the dahlia root with those of any grain. There are two principal kinds of underground roots. Those growing with a single main branch are called *primary tap roots,* while those with several main branches are called *multiple primary* or *fibrous roots.* An example of the tap root is the lupine; of the fibrous roots, the grains. When the tap root is used for food storage as in the radish, it is called a *fleshy tap root.* When the fibrous

roots store food, as in the dahlia, we have the *fleshy fibrous* or *fascicled roots.* Sketch one of each of the above kinds of roots.

Exercise 57. Roots as Organs of Absorption.

Object: To study root hairs and the path of liquids through the root.

Apparatus

Petri dishes
Blotting paper
Radish seeds
Carrot
Eosin solution

Directions: **A.** Line the bottom of a petri dish with blotting paper. Moisten it thoroughly and scatter over it a half dozen radish seeds. Cover and set aside for forty-eight hours. At the end of that time examine the roots which have been formed. The fine hair-like growths found along the surface are called *root hairs.* Are they found on all parts of the root? What is the condition of the tip of the root? The little yellow portion over the tip of the root is the *root cap* which protects the delicate portion of the root tip.

Make an accurate drawing showing root hairs and root cap.

The mineral foods for plants are dissolved in the soil water. These substances enter the roots by diffusion through the root hairs.

B. Make a longitudinal section of a carrot or any other good tap root. How many different regions do you distinguish? The central portion is the *woody part,* outside of which is the *cortex.* Surrounding the whole

is a thin skin, the *epidermis,* one layer of cells thick. Make a cross section of the carrot and identify the parts. Make a drawing of both the cross and the longitudinal sections.

To determine the paths of liquids through roots, place the cut end of a carrot in eosin solution for a number of hours. Make a cross section and examine. Indicate in the drawing of the cross section the region through which the liquid passed.

Exercise 58. External Structure of Stems.

Object: To study the external characteristics of stems.

Apparatus

Box elder twigs
Scalpel
Dissecting microscope

Directions: Procure a twig of box elder about two feet in length. Examine it carefully, noting the general characteristics of the bark. At intervals on the twig notice the small blister-like elevations, the *lenticels.* These are openings through the bark of young stems for the interchange of gases. On a twig of this season's growth, how are the leaves arranged? On the older portions of the stem note the leaf scars. Do you find any buds on the stem? What relation do they bear to the leaves or to the leaf scars? Do you find rings of narrow scars on the stem? What difference in the appearance of the stem above and below these rings? From what were these rings of scars caused?

How would you determine the age of the branch from the external markings? From the external structure, how would you distinguish a stem from a root? Draw a twig to show the above mentioned parts.

Exercise 59. Internal Structure of Stems.

Object: To study the internal structure of stems.

Apparatus

Box elder twigs	Scalpel
Corn stems	Dissecting microscope

Directions: A. Corn Stem: Take an internode of an old corn stalk. Note on the cut end the outer *rind* surrounding the *pith.* Throughout the pith note the small dots of woody substance. Break the stalk into two parts. What do you find the small dots to be? Cut a longitudinal section and follow a few of the small fibres. Do they pass the length of the internode? Through the node into the next internode? These thread-like fibres are called *fibro-vascular bundles.* Make a drawing showing these points. Under the lens of the dissecting microscope examine a cross section of the corn stem. Are the bundles regularly arranged? Where are they most numerous, near the margin or toward the center? Can you determine of what the rind is composed? Make a drawing to show these points.

B. Box Elder Stem: Make a longitudinal section of a small piece of box elder stem. How many parts do you distinguish? Where is the wood in this stem in refer-

ence to the pith? In a cross section of the stem, locate the parts seen in the longitudinal section. Note the lines running through the wood from the pith to the bark. These lines of pith are called *medullary rays.* How does the arrangement of the wood in the box elder stem differ from that in the corn stem? Make a drawing of both the longitudinal and cross section of the box elder, and label the parts. These stems are examples each of the two classes of stems of flowering plants. The corn stalk is an example of the *monocotyledenous* type, and the box elder of the *dicotyledenous* type.

Exercise 60. Functions of Stems.

Object: To determine one of the functions of stems.

Apparatus

Impatiens stem	Beaker
Eosin solution	Scalpel
Potato	

Directions: Cut off a number of branches of the Impatiens, of the Coleus, or of any other plant with a thin epidermis, and immediately place the cut end in a beaker of eosin solution. Similarly, cut off the end of a potato and place the cut end in the eosin solution. Set them aside for several hours. Then examine the stems to determine the paths taken by the red solution. To see this more clearly, make a longitudinal section of the stem. What part of the stem is stained, the pith, wood, or epidermis? Does this stain extend into the leaves? What is its course through the leaves?

Break off a leaf from the stem. Examine the end of the leaf stalk. What do the red dots on the end indicate? Through what part of the stem do liquids pass? Make a drawing of a cross section of a stem to show the path of liquids. From general observations can you suggest other functions of stems?

CHAPTER XIV

FLOWERS AND SEEDS

Exercise 61. A Typical Flower.

Object: To learn the parts of a typical flower.

Apparatus

Trillium
Dissecting microscope
Scalpel
Forceps
Needles

Directions: Carefully examine the flower of the trillium. Note the outer circle or whorl of leaf-like parts. How many are there? What is their size and shape? Each of these parts is called a *sepal;* together they form the *calyx.* The second whorl of parts forms the *corolla,* each separate part being a *petal.*

How many petals are there? How are they arranged on the flower stalk in reference to the sepals? How do they compare in size and number to the sepals? What is the nature of the parts of the third cycle of floral parts just inside of the corolla? These are the *stamens.* How many are there? How are they arranged? Remove a stamen and note the slender

stalk, the *filament*, with the enlarged end, the *anther*. On a mature anther note the powdery substance, the *pollen*. Make a drawing of a stamen showing these parts.

In the center of the flower is the *pistil*. The large bulbous base is the *ovary* and the three parted projection above is the *stigma*. Examine the stigma carefully. Is its upper surface smooth or rough? Make a drawing of the pistil and label the parts. Make a cross section of the ovary. How many compartments do you find in the ovary? How many rows of seeds in each compartment? Where are they attached? Draw a cross section of the ovary. Make a diagram of the flower showing its parts and their relation to each other. Examine a number of other flowers to acquaint yourself with the floral parts.

Exercise 62. Structure of Seeds.

Object: To study the structure and parts of seeds.

Apparatus

Scalpel	Lima beans (soaked)
Needles	Castor beans (soaked)
Dissecting microscope	Corn (soaked)

Directions:

A. Lima Bean.

(a) External structure. Examine a lima bean. What is its color, size, shape? What are the characteristics of the outer coating, the *testa* of the seed? Note the scar, the *hilum*, on the concave side of the seed. How was this formed? At one end of the

hilum, locate a small opening, the *micropyle*. Draw the bean from the side, and from the edge. Label the parts.

(b) Internal structure. With the scalpel carefully open the seed by cutting through the testa along the convex side. Again examine the testa. Within the testa notice the *embryo plant* consisting of:

(1) *the cotyledons,* two large seed leaves. Are these joined? Where?

(2) *the plumule,* the small rudimentary leaves between the cotyledons;

(3) *the hypocotyl,* the rudimentary stem and root. Draw one of the cotyledons showing the plumule and the hypocotyl in position, labeling parts.

B. Corn.

In the bean, the entire contents of the seed consist of the embryo; but this is not always the case. Often, as in corn, food is stored in a part called the *endosperm*.

(a) External structure. Examine a kernel of corn. Note the outer covering; also notice the groove where the embryo lies. The hilum and micropyle are at the small end of the kernel. Draw the flat side of the kernel showing the position of the embryo.

(b) Internal structure. Remove the skin. Cut the kernel lengthwise, perpendicular to the flat surface. Most of the outside of the kernel consists of a white flowery substance, the *endosperm*. Of what use is this? Find the embryo. Locate the plumule, radicle, or root, and the cotyledon. Compare each of these parts with

corresponding parts in the bean. Draw a longitudinal section of the corn, showing and labeling the cotyledon, plumule, radicle, and endosperm.

C. Castor bean.

Compare the parts of the castor bean with those of the lima bean and corn.

Exercise 63. Seed Dispersal.

Object: To see how seeds are adapted for the purpose of distribution.

Apparatus

The available seeds and fruits of your locality

Directions: Seeds are scattered in various ways by wind, water, animals, and by some contrivance for forcibly expelling the seeds. Examine the seeds and fruits supplied you, and classify each according to its means of distribution as follows:

Seed or Fruit	Wind	Water	Animal	Other Methods	How Adapted
Dandelion					
Stick-tights					
Burdock					
Wild-cherry					
Milkweed					
Wild geranium					
Morning-glory					
Impatiens					

Exercise 64. Conditions for Germination.

Object: To determine the best conditions of temperature, moisture, and air supply for the germination of seeds.

Apparatus

Wide mouth bottles
Rubber stoppers
Blotting paper
Thermometer
Soaked seeds, peas, corn, etc.
Refrigerator
Oven

Directions: A. Relation of temperature to germination.

In the bottom of each of the four wide mouth bottles, place several layers of thoroughly moistened blotting paper. In each bottle put twelve soaked pea seeds. With the conditions of moisture, light, and air-supply the same for all bottles, place them in different but fairly constant temperatures. Place:

1. the first bottle on the ice in the refrigerator;

2. the second bottle on the shelf in the refrigerator;

3. the third bottle in the room;

4. the fourth in an oven at a temperature of 100° F.

With a thermometer obtain and record the exact temperature in each instance. Make daily observations for a week, tabulating your results as follows:

Bottle	Temp.	24 hrs.	48 hrs.	72 hrs.	96 hrs.	120 hrs.
A_1						
A_2						
A_3						
A_4						

What do you conclude from the above experiment is the best temperature for the germination of peas?

B. Relation of moisture to germination.

Place seeds in four wide mouth bottles as follows:

1. twelve dry seeds in a bottle in which there are several layers of barely moistened blotting paper;

2. twelve soaked seeds in a bottle with barely moistened paper;

3. twelve soaked seeds in a bottle with thoroughly wet paper;

4. twelve soaked seeds in a bottle and almost cover them with water.

Place these bottles aside under similar conditions of temperature, light, and air supply. Make daily observations for a week and tabulate results as above. What do you conclude from this experiment?

C. Relation of air supply to growth.

Place several layers of blotting paper in each of two bottles. Moisten the paper thoroughly. Fill each bottle one-third full of soaked seeds. Cork one of the bottles tightly making it air tight, and leave the other open. With all other conditions the same, set the bottles aside. At the end of 48 hours examine the seeds in each bottle and record results. Is air necessary for the germination of seeds?

Exercise 65. Seedlings.

Object: A general study of seedlings.

Apparatus

Wide mouth bottle	Seedlings, peas, corn, etc.
Mosquito netting	Scalpel

Directions: **A.** Make observations on a number

of seeds just beginning to sprout. Review the parts of the embryo in Exercise 62. What part of the embryo emerges first from the seed coat? At what point does it come through? Into what part of the mature plant does it develop? Make a sketch to show these points.

B. To determine one of the functions of a cotyledon, set up the following experiment:

Fill a wide mouth bottle with water. Cover the mouth of the bottle with mosquito netting. Choose four young seedlings of about the same size each of corn, pea, and lupine. From two of each kind carefully remove the cotyledons. Then suspend all the seedlings from the netting with the roots projecting into the water. After a week make observations on the growth of the seedlings with cotyledons, and compare with the growth of those from which the cotyledons were removed.

C. Methods of emerging from the soil.

In a pot of germinating seeds of the castor bean, squash or lima bean, and corn, or any other grain, make observations on various stages of the growth of the seedlings. In the castor bean, squash, or lima bean, what part of the seedling emerges from the soil first? In what manner does it come above the surface? Of what advantage is this method to the seedling? Does the arch persist after the cotyledons and plumule are above the surface?

Sketch at least three stages in the above develop-

ment. Make similar observations on the corn. In what manner does it send its shoot through the soil? Sketch. Examine a number of other seedlings and place them under the proper one of the above classes.

D. The growth above the ground is called the *shoot* (stem and leaves), while that below is the *root.* The points on the stem from which the leaves grow are called *nodes.* The portion of the stem between two nodes is the *internode.* Sketch a pea seedling to show nodes and internodes.

Examine well grown seedlings of peas and beans. In each instance where are the cotyledons, above or below the surface of the soil? What is their present condition? What does this indicate as to the function of the cotyledons? What change has the plumule undergone? Is there a new plumule? Sketch to show the above points.

CHAPTER XV

FRIENDS AND ENEMIES OF LIVING ORGANISMS

Exercise 66. Bacterial Cultures.

Object: To show the prevalence of bacteria and something of their nature.

Apparatus

Petri dishes	Steam sterilizer
Culture media (gelatine, agar, and potato)*	Inoculating tubes
	Dissecting needles

*Culture media ready for use may be obtained from dealers in laboratory supplies.

Directions: Thoroughly wash all dishes and other apparatus to be used in this exercise. Follow this by dipping each article separately into alcohol. Then place the dishes in the steam sterilizer and heat at a temperature of 150° C. for a period of twenty minutes. If gelatin culture medium is used, mix together the following:

200 c.c. of water.
1 gram extract of beef.
2 grams of peptone.
20 grams of gelatin.

Place the mixture in the dish in which it is to be boiled, heat until the gelatin is thoroughly melted, and then boil briskly for a few minutes. Test with litmus paper. The solution should be slightly alkaline. If it is not, add to it, drop by drop, a solution of sodium hydroxide until it is slightly alkaline to litmus paper. Filter the solution through absorbent cotton and collect the clear liquid in a sterilized flask. Into the sterilized petri dishes pour enough of the medium to cover the bottom of the dish. Cover the dishes immediately, place them in the sterilizer, and heat at a temperature of 150° C. for fifteen minutes. When cooled sufficiently to handle, set aside for twenty-four hours, then heat again at 150° C. for fifteen minutes. After another twenty-four hours repeat the sterilization process. The medium is now thoroughly sterilized

(if properly done) and is ready for inoculation. The agar medium is prepared in the same way, except that instead of using 20 grams of gelatin, use 2/5 of a gram of agar. In all other respects the culture is made precisely as the gelatin culture medium. Potato may be used by paring and placing thin cut slices in the sterilized dishes. Sterilize as indicated above.

1. After the medium has hardened, expose the medium of one dish to the air of the laboratory for three minutes. Cover the dish, label it No. 1, and set aside until the next recitation period.

2. At the same time expose the medium of another dish to the air out of doors for three minutes. Cover and label No. 2, and set aside.

3. Touch the surface of the medium of a third dish with the fingers in several places. Cover, label No. 3, and set aside.

4. Over the surface of the medium of a fourth dish, roll the end of your lead pencil (which you so frequently place in your mouth). Cover, label No. 4, and set aside.

5. If a fly is obtainable, capture it, and place it inside another dish, permitting it to walk over the surface of the medium. Free the fly, cover the dish and label No. 5. Set aside until next recitation.

6. Set one dish aside unopened as a check, and label No. 6.

Place all vessels under similar conditions of light, heat, etc. Make daily observations for the appearance

of colonies of bacteria. Describe and sketch the appearance of the growths. What do these experiments show as to the prevalence of bacteria?

Exercise 67. Conditions for Bacterial Growth.

Object: To determine conditions for bacterial growth.

Apparatus

Hay	Test tubes
Milk	Absorbent cotton
Meat	

Directions: **A.** Prepare three test tubes as follows: Put in one some pieces of chopped hay and cover with water; in the second some milk; and in the third a small piece of meat covered with water. Set these aside, uncovered, for a few days and note the changes in appearance and odor of the contents. Mount some of the scum on a slide and cover with a cover glass. The instructor will find the bacteria for you under the high power of the microscope. Determine the shape of some of these bodies and sketch.

B. Prepare three test tubes as follows: Fill each tube half full with milk. Place one in a beaker and pack ice around it. Leave the top open. Set the entire apparatus on ice in the refrigerator. Boil the contents of the second tube for a few minutes and stopper with sterilized absorbent cotton. Set aside in a warm place. Place the third tube, uncorked, in a

warm place. Make daily observations and record results. What is the effect of heat on bacteria? Of cold?

C. Prepare two test tubes as follows: Boil two test tubes in water and fill each half full of boiled milk. Into one tube introduce some of the scum from the tube of hay infusion. Close the tube with absorbent cotton and set in a warm place.

Take some scum from the hay infusion and mix it with a teaspoonful of a 2% solution of corrosive sublimate, or of formalin, and let it stand ten minutes. Then pour this mixture into the second tube. Close with absorbent cotton and place beside the first tube in a warm place. After a day examine the contents of the two tubes. Is the milk still fresh in either tube? How do you account for the condition found?

From this experiment what conditions are favorable to bacterial growth? What conditions are unfavorable? What are some of the methods of killing bacteria?

Exercise 68. Root tubercles.

Object: To show a use of bacteria.

Apparatus

Compound microscope	Roots of legumes
Slides, etc.	

Directions: Bring to the laboratory the roots of any leguminous plants (pea, bean, vetch, etc.) Examine the roots carefully for nodules. Sketch to show

their distribution. Crush a portion of a nodule on a glass slide and mount a portion of the material in a drop of water. Cover with a cover glass. With the aid of the instructor, find the mass of moving bacteria under the high power microscope. Sketch to show the form of some of the bacteria. These bacteria are very helpful to the plants of the pulse family, enabling them to obtain and utilize the nitrogen from the air as food.

CHAPTER XVI

CLASSIFICATION OF FOODS

Substances which are taken into the body as nourishment are known as foods.

Foods contain many elements, chief of which are carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, and iron.

These elements do not occur in living matter as elements, but in various combinations or compounds. These compounds in foods are known as foodstuffs. There are five such foodstuffs.

Proteins, or nitrogenous compounds.

Carbohydrates, or starches and sugars.

Hydrocarbons, or fats and oils.

Mineral salts.

Water.

Each foodstuff shows certain definite qualities by which its presence may be detected.

Exercise 69. Tests for Foodstuffs.

Object: To determine a test for protein, starch, sugar, fat and oil.

Apparatus

Cornstarch	Grape sugar
Ammonia	Egg-white
Benzine and ether	Mutton tallow
Unglazed paper	Ground flax seed
Test tubes	Iodine
Evaporating dish	Fehling's solution
Filter paper	Nitric acid
Bunsen burner	Hydrochloric acid
Stirring rod	

Directions: A. Test for starch: Place a small amount of cornstarch in a test tube. Add water and shake the mixture. Does the starch dissolve? (To answer this question compare this mixture with a solution of salt and water.) Boil the mixture. What change do you note? Dip the end of a glass stirring rod into the paste. Over the paste on the glass rod pour a few drops of iodine. What is the result?

B. Test for grape sugar: Place a small amount of grape sugar in a test tube and add enough water to dissolve it. What is the difference in the effect of water on sugar and starch? Add a few drops of Fehling's solution and boil. What change do you observe? To a solution of cane sugar add Fehling's

solution and boil. Do you obtain the same result? Take a fresh solution of cane sugar, add a few drops of hydrochloric acid, then Fehling's solution and boil. How does this result compare with the two preceding? Thus cane sugar is converted into grape sugar by the acid.

C. Tests for protein: Into a test tube half full of water, place some raw egg-white. Heat this over the Bunsen flame. What is the effect of heat on the egg-white? Pour off the water. Cover the egg-white with dilute nitric acid and boil. What is the color of the egg? Pour off the acid. Add enough ammonia to cover the egg. What is the color produced?

D. Tests for oil and fat: To four teaspoonfuls of ground flax seed, add an equal volume of benzine or ether. Thoroughly stir the mixture and let it stand for about ten minutes. Filter and place the filtrate aside in a strong draught of air until the benzine or ether has entirely evaporated. What is the substance left? What is the odor? Why are benzine and ether used to remove grease spots from clothing?

Rub some mutton tallow on the surface of a piece of unglazed paper. Hold the paper over a Bunsen flame to melt the fat. Then hold it to the light. What is the effect of fat or oil on paper? Summarize the tests you have learned for protein, starch, sugar, fat.

Exercise 70. Foodstuffs in Common Foods.

Object: To determine the foodstuffs found in some foods.

Apparatus

Egg-white	Iodine
Milk	Nitric acid
Potato	Fehling's solution
Apple	Ammonia
Beans (soaked)	Unglazed paper
English walnuts	Bunsen burner
Flour	

Directions: Apply the four tests, which you have learned in Exercise 69, to each of the following foods and tabulate your results as follows:

Foods	Starch	Grape Sugar	Protein	Oil and Fat
Egg-white				
Milk				
Potato				
Apple				
Beans				
English-walnuts				
Flour				

CHAPTER XVII

DIGESTIVE SYSTEM

Exercise 71. Study of the Mouth (home study).

Object: To study the parts and structure of the mouth.

Apparatus

Hand mirror

Directions: Take a position with your back toward a strong light, and study your mouth cavity with the aid of a hand mirror.

A. Walls of the mouth cavity.

1. How do the walls enclosing the mouth cavity differ from each other? Note the hard portion or roof of the mouth. How far back does it extend? This is called the *hard palate.* The softer portion at the back of the mouth is called the *soft palate;* hanging down from its free border is a conical projection, the *uvula.* What is its function?

2. What difference do you observe between the outer and inner covering of the cheeks? What are the characteristics of the inner covering, or *mucous membrane?*

B. Salivary glands.

1. Pull aside with the fingers one corner of the mouth. Find the small elevation on the inside of the cheek. The duct from one of the salivary glands (*parotid gland,* lying close in front of the ear) opens on this elevation.

2. Lift the tongue and note the glands (*sub-lingual*) lying just beneath. The ducts from these glands open in the front of the mouth beneath the tongue. Feel them with the tip of the tongue.

3. Find the third pair of salivary glands (*sub-maxillary*) lying beneath the floor of the mouth just behind the sub-lingual near the angle of the jaw.

C. The tongue.

What kind of covering has the tongue? Describe the difference between the upper and under surfaces. Can you see any difference in the size, shape, number,

and arrangement of the minute elevations (*papillae*) on the upper surface?

D. The teeth.

1. Teeth differ in minor points from one another, but in all, three parts are found: one, seen in the mouth and called the *crown* of the tooth; a second, imbedded in the jawbone and called the *root;* and between the two surrounded by the edge of the gum, the *neck* of the tooth.

2. Count the teeth in the upper and lower jaws. How many in all? Describe the edges of the front teeth (*incisors*). How many teeth have this sharp cutting edge? How does the tooth (*canine*) next to the incisors differ from the other teeth? What is its function? How many teeth have two points to the crown? These are known as *bicuspids.* What is the character of the last three teeth? What is their function? These are the *molars.* Do you have all the molars? Why not?

E. Tonsils.

The opening from the back of the mouth leads into the throat. Press the tongue down and note the almond shaped elevations at the sides of the throat. These are called *tonsils.*

Exercise 72. Alimentary Canal and Digestive Glands. (Demonstration.)

Object: A study of digestive organs.

Apparatus

Models of digestive organs Charts

Directions: On the models and charts locate the parts of the alimentary canal.

A. Alimentary Canal. At the back of the mouth note the funnel-shaped cavity, the *pharynx* or throat. What other openings are there into this cavity? What openings lead from this cavity?

Note the gullet or *esophagus,* a small tube leading from the pharynx to the *stomach.*

What is the position of the stomach in the body? Its approximate size and shape?

Following the stomach is a long, very much coiled tube, the *small intestine.* This tube connects with a larger tube known as the *large intestine.*

B. Glands. The *salivary glands* of the mouth, the parotid, the sub-maxillary, and the sub-lingual were studied in Exercise 71.

In the internal walls of the stomach are small glands known as *gastric glands.* These discharge their secretion into the stomach.

Intestinal glands are located in the walls of the first part of the small intestine. Other glands which pour their secretions into the small intestine are the *pancreas* and the *liver.*

The pancreas is a long, lobulated gland lying beneath the stomach. The liver, the largest gland in the body, lies just beneath the diaphragm above and to the right of the stomach.

From the chart make a drawing of the alimentary canal and glands, labeling parts.

CHAPTER XVIII

DIGESTION AND ABSORPTION

Exercise 73. Digestion in the Mouth.

Object: To determine the foodstuffs acted upon by saliva.

Apparatus

Litmus paper	Iodine
Corn starch	Test tube
Egg-white	Test tube rack
Olive oil	Test tube clamp
Hydrochloric acid	Bunsen burner
Fehling's solution	

Directions: Food is first acted upon by a fluid, saliva, which is secreted by glands discharging into the mouth. Test saliva by placing a piece each of red and blue litmus paper upon the tongue. Is saliva acid or base? Dry the mouth as much as possible by swallowing and then place on the top of the tongue a pinch of salt. Can you taste the salt? Keep the salt on the tongue for a minute. What happens to the salt? Can you now taste it?

To determine the chemical action of saliva on the foodstuffs, prepare test tubes as follows:

In the first, place a small amount of thin starch paste, to which add a few c.c. of saliva. Label No. 1.

In the second, place some starch paste and saliva, to which add a few drops of hydrochloric acid. Label No. 2.

In the third, place a few small bits of egg-white and cover with saliva. Label No. 3.

In the fourth, place a few c.c. of olive oil and saliva. Label No. 4.

Shake the tubes and set them in a basin of water having a temperature of 36° C., or about body temperature. Leave them for half an hour and then test the contents of the tubes.

Tube No. 1—Test part of the contents for starch and the remainder for sugar.

Tube No. 2—Repeat the test applied to tube No. 1.

Tube No. 3—Has the egg-white begun to dissolve?

Tube No. 4—Has any change taken place in the oil?

Upon which of the foodstuffs does saliva act?

Does it act in an acid or base solution?

Exercise 74. Digestion in the Stomach.

Object: To determine the foodstuffs acted upon in the stomach.

Apparatus

Corn starch	Test tube clamp
Egg-white	Iodine
Olive oil	Sodium hydroxide (dilute)
Milk	Pepsin
Hydrochloric acid (dilute)	Rennet
Fehling's solution	Bunsen burner
Test tubes and racks	

Directions: In the stomach the food comes in contact with the gastric juice. This contains two active substances, pepsin and rennin.

A. Pepsin.

Make a weak solution of pepsin by dissolving a few grams of pepsin in 50 c.c. of water.

Prepare five test tubes as follows:

In the first, place a small amount of starch paste, 10 c.c. of pepsin, and a few drops of very dilute hydrochloric acid. Label tube No. 1.

In the second, place a few pieces of egg-white, 10 c.c. of pepsin, and dilute hydrochloric acid. Label No. 2.

In the third, place a few pieces of egg-white, 10 c.c. of pepsin, and a few drops of very dilute sodium hydroxide solution (0.2%). Label No. 3.

In the fourth, place 5 c.c. of olive oil, 10 c.c. of pepsin, and a few c.c. of dilute hydrochloric acid. Label No. 4.

Shake the tubes and keep them at a temperature of 36° C. for 24 hours. At the end of that time test the contents of the tubes.

Test No. 1 for starch and sugar.

In No. 2, has the egg-white dissolved?

In No. 3, has the egg-white dissolved?

In No. 4, is there any change in the olive oil?

Upon which foodstuffs does pepsin act?

In comparing tubes No. 2 and No. 3 does pepsin act in a base or acid solution?

B. Rennin.

In the fifth tube place 10 c.c. of milk and 5 c.c. of rennet (which contains rennin). Set aside for 30

minutes at a temperature of 36° C. At the end of that time what change do you observe in the milk?

Exercise 75. Digestion in the Intestine.

Object: To determine the foods acted upon by the pancreatic juice.

Apparatus

Corn starch	Pancreatin
Egg-white	Bunsen burner
Olive oil	Test tubes and racks
Hydrochloric acid (dilute)	Test tube clamps
Sodium hydroxide (dilute)	

Directions: In the small intestine the food is acted upon by three digestive juices: intestinal, which is secreted by the glands in the walls of the small intestine; bile, secreted by the liver; pancreatic, secreted by the pancreas.

Prepare a weak solution of pancreatin by dissolving a few grains of pancreatin in 50 c.c. of water.

Prepare four test tubes as follows:

In No. 1 place starch paste, 10 c.c. of pancreatin solution, and a few drops of very dilute sodium hydroxide.

In No. 2 place starch paste, 10 c.c. pancreatin solution, and a few c.c. of hydrochloric acid.

In No. 3 place a few bits of egg-white, pancreatin solution, and sodium hydroxide.

In No. 4 place 10 c.c. olive oil, pancreatin solution, and sodium hydroxide.

Shake the tubes and set them aside in a temperature of 36° C. for 24 hours.

At the end of that time examine:

No. 1 for starch and sugar.

No. 2 for starch and sugar.

No. 3. Has the egg-white dissolved?

No. 4. Has the olive oil changed?

Upon which foodstuffs does pancreatin act? Does it act in an acid or base solution? From the last three exercises complete the following table:

Digestive Fluid	Acid or Base	Region of Alimentary Canal	Foodstuffs Acted Upon	Digested Product
Saliva				
Gastric				
Pepsin				
Rennin				
Pancreatin				

Exercise 76. Absorption.

Object: To determine which foodstuffs will diffuse through an animal membrane.

Apparatus

Corn starch	Thistle tube
Olive oil	Animal membrane
Egg-white (raw)	Glass jar
Iodine	Ring stand
Ammonia	Twine
Nitric acid	

Directions: For the method of setting up the apparatus for this exercise, see Exercise 5 on "Diffusion of Liquids through a Membrane." Set up similar experiments, using in place of the molasses:

a. starch paste,

b. olive oil,

c. raw egg-white.

After 48 hours note any change in the level of the liquids in the thistle tubes. At the same time test the water in which the bulbs of the thistle tubes were suspended:

a. for starch,

b. for oil,

c. for protein.

Has diffusion taken place in any of the foregoing? In Exercise 5 did molasses diffuse through the animal membrane? Why is it necessary to have foods digested?

CHAPTER XIX

CIRCULATORY SYSTEM

Exercise 77. Study of Beef "Pluck." (Demonstration.)

Object: A study of the relation of the heart and lungs and their structure.

Apparatus

Beef "pluck," to consist of the trachea, lungs, heart, and its covering, and the main blood-vessels leading to and from the heart

Plaster model

Scissors

Scalpel

Large glass tube

Directions: A. In what part of the body are these

organs located? What is their position to each other? Notice the trachea with its circular rings of cartilage. Are the rings entire? These are necessary to prevent collapse of the tube. How far down do these rings continue? With a scalpel follow a branch of the trachea into the lungs. How do these branches end? This large amount of branching allows the air to be brought in contact with very small blood vessels, through the walls of which oxygen is absorbed into the blood.

B. Lungs. How many lobes has each lung? What are their relative sizes? Note the texture of the lungs. By inserting a glass tube into a branch of one of the bronchi, force air into the lung. What happens? The lungs are the organs chiefly concerned in breathing.

C. Heart. What is the general shape? The covering about the heart is the *pericardium*. The heart has four compartments: the upper two, the *auricles* (right and left); the lower two, *ventricles* (right and left). Which parts have the thickest walls? The walls are made of muscle with the thick-walled parts doing the pumping.

Find the blood vessels, *superior* and *inferior vena cava*, leading into the right auricle. Open the veins, also the walls of the auricle, and observe the path of the blood into the right ventricle. Note the *tricuspid valve* that closes this entrance between auricle and ventricle. Also notice the *cords* by which this valve

a. starch paste,

b. olive oil,

c. raw egg-white.

After 48 hours note any change in the level of the liquids in the thistle tubes. At the same time test the water in which the bulbs of the thistle tubes were suspended:

a. for starch,

b. for oil,

c. for protein.

Has diffusion taken place in any of the foregoing? In Exercise 5 did molasses diffuse through the animal membrane? Why is it necessary to have foods digested?

CHAPTER XIX

CIRCULATORY SYSTEM

Exercise 77. Study of Beef "Pluck." (Demonstration.)

Object: A study of the relation of the heart and lungs and their structure.

Apparatus

Beef "pluck," to consist of the trachea, lungs, heart, and its covering, and the main blood-vessels leading to and from the heart	Plaster model
	Scissors
	Scalpel
	Large glass tube

Directions: A. In what part of the body are these

organs located? What is their position to each other? Notice the trachea with its circular rings of cartilage. Are the rings entire? These are necessary to prevent collapse of the tube. How far down do these rings continue? With a scalpel follow a branch of the trachea into the lungs. How do these branches end? This large amount of branching allows the air to be brought in contact with very small blood vessels, through the walls of which oxygen is absorbed into the blood.

B. Lungs. How many lobes has each lung? What are their relative sizes? Note the texture of the lungs. By inserting a glass tube into a branch of one of the bronchi, force air into the lung. What happens? The lungs are the organs chiefly concerned in breathing.

C. Heart. What is the general shape? The covering about the heart is the *pericardium*. The heart has four compartments: the upper two, the *auricles* (right and left); the lower two, *ventricles* (right and left). Which parts have the thickest walls? The walls are made of muscle with the thick-walled parts doing the pumping.

Find the blood vessels, *superior* and *inferior vena cava*, leading into the right auricle. Open the veins, also the walls of the auricle, and observe the path of the blood into the right ventricle. Note the *tricuspid valve* that closes this entrance between auricle and ventricle. Also notice the *cords* by which this valve

number? In size? The smaller are called *red corpuscles.* How are they arranged? Can you make out their shape? Make two drawings of a red corpuscle, one as seen on end, the other from the side.

The larger bodies are the *white corpuscles.* Describe them.

CHAPTER XX

RESPIRATORY SYSTEM

Exercise 79. Respiratory Organs and Mechanics of Respiration. (Demonstration.)

Object: To study the organs and mechanics of respiration.

Apparatus

Chart or plaster model	Sheet rubber
Skeleton	Rubber balloon
Mechanical device for rib action	Glass tube
Belljar with stopper	

Directions: A. The lungs are the chief organs of respiration. The structure of the lungs was studied in Exercise 77, in the study of the beef "pluck." Note on the chart or plaster model their position in the body. The cavity in which the lungs and heart are found is the *thorax.* On the skeleton note the bones forming the frame work of this cavity. The floor of the thorax is a muscular sheet called the *diaphragm.* Note on the skeleton the attachment of the ribs to the sternum by means of cartilage. This permits the

movement of the ribs by the action of the muscles between the ribs called the *intercostals.*

To demonstrate this movement use the mechanical device.

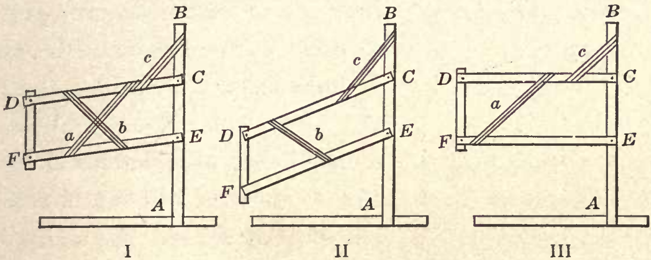


Fig. 30.

The vertical bar *AB* represents the *spinal column, DF* the *sternum, CD* and *EF two ribs.* Letter *c* represents the muscular attachment from the *spine* and *collar bone* to the *ribs.* Letters *a* and *b* represent *intercostal muscles.*

Note on the skeleton that the ribs slant downward toward the sternum. On the device place the bar *DF* lower than points *CE.* Measure the perpendicular distance between *CE* and *DF.* Then lift the ribs *CD* and *EF* to a position perpendicular to *AB* (in the body this movement is brought about by the contraction of the intercostal muscles). Again measure the perpendicular distance between *CE* and *DF.* How does it compare with the first measurement? How has the position of *DF* been affected? How does this movement affect the size of the thoracic cavity?

B. The thoracic cavity is enlarged vertically by the

movements of the diaphragm. This action is demonstrated by the following experiment:

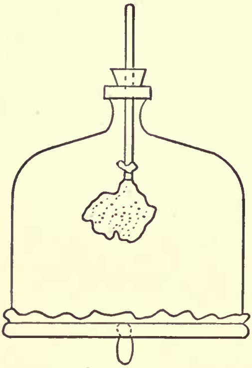


Fig. 31.

Fasten a toy balloon to one end of a glass tube. Insert the tube into a rubber stopper and fit this into the belljar with the balloon suspended inside. Over the other end of the belljar, securely fasten the rubber sheet to the center of which a handle has been attached. The belljar represents the chest walls, the tube the trachea, and the balloon a lung. The rubber sheet represents the diaphragm.

Pull the rubber sheet downward. What happens to the balloon? Then let the rubber sheet return to its normal position. What is the effect on the balloon? The action of the balloon represents the action of the lungs in response to the movements of the diaphragm.

Exercise 80. Comparison of Expired and Inspired Air.

Object: To determine the changes which take place in the air while in the lungs.

Apparatus

Thermometer	Glass tubing
Glass plate	Lime water
Wide mouth bottles	Pine splinter
Two-holed rubber stopper	Pneumatic trough

Directions: A. Temperature. Expose the thermometer to the room temperature for five minutes and record the temperature. Then breathe on the bulb of the thermometer for a few minutes and record the temperature of expired air. What change has taken place in the temperature of the air while in the lungs?

B. Composition. For the composition of inspired air see Exercise 38.

a. Breathe on the glass plate. What collects on the surface? Does expired air contain more or less moisture than inspired air?

b. Into a wide mouth bottle pour lime water to the depth of an inch. Fit the mouth of the bottle with a rubber stopper fitted with a long and short glass tube. Adjust the long tube so that the end is below the level of the lime water. Draw air from the room through the lime water by suction applied to the free end of the short tube. Continue this for two minutes. Insert the stopper with the tubes into a second bottle containing lime water. Pass expired air through the lime water by blowing into the free end of the long tube. Continue this for two minutes. How does the lime water in the two bottles compare? Which contains the greater amount of carbon dioxide, inspired or expired air?

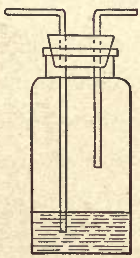


Fig. 32.

c. Fill a bottle with expired air by downward displacement of water. Turn the bottle mouth upward

and introduce into it a burning splinter. Does the splinter continue to burn as brightly as in the air? What does this indicate?

Air expired in ordinary breathing has lost about one-fourth of the oxygen contained in inspired air.

Exercise 81. School Ventilation.

Object: To determine the efficiency of the room ventilation.

Apparatus

Tape measure

Directions: For a sufficient air supply most authorities agree that an individual requires 300 cu. ft. of space with 1,800 cu. ft. of air per hour.

With the tape measure determine the dimensions of the laboratory. From the dimensions what is the volume of the laboratory in cubic feet?

Divide the cubic contents of the laboratory by the number of people in the room. How does the quotient compare with the number of cubic feet of space each individual should have?

What is the method of ventilation in the school building? Learn from those in authority the number of times per hour the air is changed in the room. Compute from this data the number of cubic feet of air each person receives per hour. Is this sufficient for the individual?

Follow the same directions in computing the volume of your session room. Divide the cubic contents by

the number of students in the room. Determine the number of cubic feet of air each individual receives per hour. Has each individual the requisite amount of air? If not, what change would you suggest to meet the requirements?

For your own information compute the volume of your sleeping room in cubic feet. How long would the air in the room suffice without change? What means are there for changing the air in the room? Are these sufficient? From what you have learned above, correct the fault.

CHAPTER XXI

EXCRETORY SYSTEM

Exercise 82. The Kidneys.

Object: To study the structure of a kidney.

Apparatus

Sheep kidney	Scalpel
Dissecting pan	Scissors

Directions: Describe the capsule surrounding the kidney. Where is it attached to the kidney? Slit the capsule on the convex side enough to allow the kidney to be removed. Cut the kidney longitudinally from the convex border toward the hilum sufficiently to open the cavity within.

What is the shape of the kidney? Size? Color? How many tubes do you find connected with this organ? In the longitudinal section of the kidney notice two

parts: the outer solid part, the *cortex*; the inner striated part, the *medulla*. The slight elevations are called *pyramids of Malpighi*, between which small tubes may be seen leading into the *sinus*. The tube leading from the sinus is the *ureter* which carries the excretion into the *bladder*. Notice the enlarged end of the ureter in the sinus. Note also the entrance of the *renal artery* and the *renal vein* into the kidney just above the ureter. The artery brings in the blood which gives up its waste in the kidney. This waste is collected by the tubules and emptied from the sinus into the ureter. The capillaries collect the blood which has been cleared of waste and return it to the vein.

Exercise 83. The Skin.

Object: To study the structure and functions of the skin.

Apparatus

Plaster model of skin

Directions: A. External structure: The outer layer of the skin is called the cuticle, or the *epidermis*. What is its color? Thickness? Where is it thickest on the hand? What markings do you find on it? Can you find the pores, openings of the sweat glands? Does the epidermis contain blood vessels? Does it contain nerves?

B. Internal structure: From the plaster model, or a prepared slide of the skin, note the two layers comprising it. Note the epidermis again. What is its

structure? The inner layer is the *dermis.* How does it compare with the epidermis in thickness? Note that its surface is ridged. These ridges are made up of a number of *papillae.* Each papilla marks the end of a nerve of touch. Is the skin sensitive to other stimuli than touch? If so, what are they? In the dermis locate the *fat cells,* the *roots* of the *hair,* the oil or *sebaceous glands,* and the *sweat glands.* Where do the ducts from the sweat glands open? What effect does the evaporation of sweat from the surface of the skin have on the temperature of the skin? To answer this question refer to Exercise 21.

Make a drawing to show the parts of the skin.

From this exercise what are some of the functions of the skin?

Hair and nails are modifications of the skin.

CHAPTER XXII

SKELETAL SYSTEM

Exercise 84. The Skeleton.

Object: To study the general plan of the skeleton.

Apparatus

Skeleton

Directions: The skeleton may be divided into three parts: the head, trunk, and limbs with the bones to which they are attached, hip and shoulder.

A. Head. Notice that the head is divided into the

face and the *cranium.* The face is composed of a number of irregular bones. The cranium consists of a number of flat bones, sutured together to form a strong covering for the brain.

B. Trunk. The trunk consists of the *spinal column, breast-bone,* and *ribs.*

The spinal column is composed of a number of irregular bones called *vertebrae.* The upper seven are the neck, or *cervical vertebrae.* The next twelve to which the ribs are attached are the *dorsal vertebrae.* The five following are the *lumbar vertebrae.* The next five in the adult are grown together, forming the *sacrum.* This is followed by four small vertebrae united to form the *coccyx.*

How do the lower vertebrae compare in size with the upper? What are the advantages of this arrangement?

Note the pads of cartilage between the vertebrae. What is their purpose? Through the center of this chain of bones is a canal which contains the spinal cord. How many curves in the backbone? Of what advantage are the curves? Note the flat breast-bone. Of how many bones is it composed? What bones are attached to it?

How many ribs are there? Where are they attached? How many have one end free? What is their general shape?

C. Limbs. The shoulder consists of the *shoulder blade* and *collar bone.* Locate these. Note the socket

formed by their union for the upper limb. The upper limb consists of the upper arm bone, the *humerus;* two bones in the forearm, the *ulna* and *radius;* eight irregular wrist bones, the *carpals;* five bones in the palm of the hand, the *metacarpals;* and fourteen bones in the fingers, the *phalanges.*

The hip consists of one large bone on each side. Notice the size and strength of the hip as compared with the shoulder. Why this difference?

The lower limb consists of the upper leg bone, the *femur;* the two lower leg bones, the *tibia* and *fibula;* the knee cap or *patella;* seven ankle or *tarsal* bones; five *metatarsals;* and fourteen toe bones or *phalanges.*

Compare each of these parts with the corresponding parts in the arm.

Exercise 85. Structure and Composition of Bone.

Object: To study the structure and chemical composition of bone.

Apparatus

Section of a long bone (femur)	Hydrochloric acid 20%
Beef rib	Glass cylinder

Directions: **A.** Structure. Examine a long bone. Note the long central shaft with enlarged ends. Of what advantage are the enlarged ends? Note the pinkish colored covering surrounding the bone. What is its function? This covering is the *periosteum.* Make a longitudinal section through the bone. Beneath the periosteum note the *hard bone;* inside of this the *spongy*

bone and *central canal.* The spongy bone contains in its cavities *red marrow,* while the central canal contains *yellow marrow.*

B. Composition. To determine the chemical composition of bone, place a rib in a twenty per cent solution of hydrochloric acid. Leave the bone in the solution for at least four days. At the end of that time examine the bone. Has it changed in shape? Can it be cut? Is it elastic? The acid has dissolved from the bone the *mineral matter* leaving only the animal matter, *cartilage.* The animal matter may be extracted by burning the bone. Again the shape remains the same but the substance left is hard and brittle. This mineral matter is chiefly lime.

CHAPTER XXIII

MUSCULAR SYSTEM.

Exercise 86. Levers.

Object: To determine the action and advantages of levers.

Apparatus

Yard stick	Ring stand
Weight (500 gms.)	Lever holders
Spring balance	

Directions: A lever is an inflexible bar moving about a fixed point, called a *fulcrum,* and having two other points, called *power* and *weight.* Weight is the

mass moved. Power is the force used to move the mass. *Weight arm* (W. A.) is the distance from the fulcrum to the point of application of the weight.

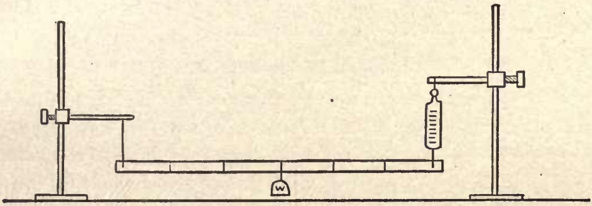


Fig. 33.

Power arm (P. A.) is the distance from the fulcrum to the point of application of the power.

Levers are divided into three classes based upon the relative positions of the three points: fulcrum, power, and weight.

In the first class lever, the fulcrum is in the middle, the weight at one end, and the power at the other.

The second class lever has the fulcrum at one end, the power at the other end, and the weight in the middle.

The third class lever has the fulcrum at one end, the weight at the other end, and the power in the middle.

Fasten one end of the yard stick to the ring stand. From the second ring stand suspend the spring balance. Wire the free end of the yard stick to the hook of the spring balance. Take the reading of the indicator on the scale. Suspend the 500 gm. weight from the zero point on the yard stick.

Locate on the apparatus the fulcrum, the power, weight, power-arm, and weight arm.

Shift the weight on the bar, and record the readings on the balance with the weight at 0, 6, 12, 18, 24, 30, and 36 inches from the fulcrum.

Tabulate your readings as follows:

Power × Power-arm =	Product	Weight × Power-arm =	Product

How do the two product columns compare? What class of lever is used in this exercise?

Of what mechanical advantage is the lever in lifting the 500 gm. weight as shown by the reading at the 6-inch point?

How would you convert this apparatus into a third class lever? Into a first class lever?

From the results of this exercise what law can you deduce for levers?

Exercise 87. Muscles. (Demonstration.)

Object: To determine the structure and action of muscles.

Apparatus

Frog
Dissecting pan
Scalpel
Scissors
Needles

Directions: Dissect away the skin of a frog's leg. Note the muscles on the leg. What is the general shape of the muscle? Note the tendon attachment of the muscles to the bone. Of what advantage is the tendon attachment? Note that the body of the muscle is surrounded by a thin sheet of connective tissue. Find the large muscle on the calf of the leg. Where are its two ends attached? What effect does the contraction of this muscle have upon the lower leg? Upon the foot? The bones of the skeleton serve as places for muscle attachment and as levers for their action.

CHAPTER XXIV

NERVOUS SYSTEM

Exercise 88. Nervous System. (Demonstration.)

Object: To study the brain, spinal cord, and nerves.

Apparatus

Perch	Scalpel
Dissecting pan	Model of human brain
Scissors	

Directions: Carefully dissect away the roof of the cranium and the dorsal part of the spinal column of the fish to expose the brain and the spinal cord. Note that the brain is divided into a number of regions: the small anterior lobes, the *olfactory lobes;* the larger *cerebral hemispheres;* the rounded *optic lobes;* the single lobed *cerebellum;* and behind this, tapering gradually into the spinal cord, the *medulla oblongata.*

From these centers branches lead to all parts of the head and to some of the internal organs.

Examine the spinal cord in the fish. Is it of the same dimensions throughout its length? Note the numerous lateral branches. Are they single or in pairs? These are distributed to the remaining parts of the body.

Examine the model of the human brain. Observing the upper surface of the brain, note the two large convoluted (folded) hemispheres of the fore-brain, or *cerebrum.* At the base of the cerebrum note the smaller lobes of the *cerebellum.* How do the convolutions on the cerebellum compare in size with those of the cerebrum? What is the color of each?

On the under surface of the brain, note again the cerebral hemispheres and the cerebellum. How do they compare in size? At the forward end of the cerebrum note the two small white *olfactory lobes.* Back of these note the two nerves which cross. These are the *optic nerves.* The third portion of the brain is the *medulla oblongata.* On the model it is the white portion lying just beneath and in front of the cerebellum. Extending downward from the medulla is the *spinal cord* which continues through the spinal column.

Nerves are given off in pairs from the brain and *spinal cord* which continues through the spinal column.

On the model of the longitudinal section of the brain, locate the parts mentioned above.

CHAPTER XXV

ORGANS OF SPECIAL SENSES

Exercise 89. Cutaneous Sensations.

Object: A study of the sensations of touch and temperature.

Apparatus

Metal compasses
Hot water
Cold water

Directions: A. One pupil should operate, another acting as subject. The subject should be blindfolded. What is the least distance apart at which the two points of the compass may be held and felt as two points, when applied to the tips of the fingers? The tip of the tongue? Back of the hand? Back of the neck? Record results. Are all parts of the body equally sensitive to touch? Which parts are most sensitive?

B. Dip a point of the compass in cold water and move it lightly over the back of the hand. Does it feel equally cold to all parts of the hand? Mark with an ink dot those spots where the sensation is most acute. Now dip the compass point in hot water, and repeat the experiment. Locate as before, the points where the sensation is most acute. Do the hot and cold spots coincide? Test other areas of the body in the same way. Are all parts of the body equally sensitive to temperature? Which parts are most sensi-

tive? Least sensitive? Where are the hot spots most numerous? Where are the cold spots most numerous?

C. Do we derive any sensations other than touch and temperature through the skin? If so, what are they?

Exercise 90. Organs of Taste and Smell.

Object: A study of the tongue and the sensations of taste and smell.

Apparatus

Sugar	Quinine
Salt	Onion
Vinegar	

Directions: A. With the aid of a mirror examine the upper and lower surfaces of the tongue. What differences do you note? The raised points on the upper surface are called *papillae.* Observe that they are of three forms: long and slender, *filiform;* small, red, mushroom shaped spots, *fungiform;* far back on the tongue the large *circumvallate* papillae. How many of them can you see? Draw an outline of the tongue, and locate on it the regions where these different forms are to be found.

B. Place some sugar on the tip of the tongue. Let it dissolve. Has it any taste? Repeat, placing the sugar at the back of the tongue. Is its sweetness more or less prominent? Repeat again, using quinine, vinegar, and salt successively. Where are the sensations of bitterness, sourness, sweetness, and saltiness most prominent?

C. The sense organs of smell are located in the

mucous membrane lining the upper part of the cavity of the nose. Particles of matter in the form of a gas striking this membrane stimulate the nerves of smell, *olfactory* nerves. To determine which of the substances named under "Apparatus" have taste and which have odor, perform the following experiment. Place each of these substances on the tongue of a pupil who has been previously blindfolded, and who is holding his nose tightly. Record the substance recognized by taste alone. Repeat, leaving the nose free. Record the substances recognized by smell alone; by taste and smell combined.

Exercise 91. Organ of Sight.

Object: To study the structure and action of the eye.

Apparatus

Model of human eye	Lenses

Directions: A. With the aid of a mirror examine the eye. Feel the upper eyelid; fold it. In what part of it is there a stiff, thick strip of connective tissue? Compare with this the corresponding strip in the lower lid. At the angle of the lower lid, about one-eighth of an inch from the inner corner, look for a little papilla in which is the opening of the tear duct. Can you find a similar opening in the upper lid? Notice the eyeball. What do you find in the inner corner which is different from the outer? The eye

is covered with a firm white coat, the *sclerotic,* except in front where there is a clear layer, the *cornea.* Look at your neighbor's eye from the side. Does the cornea curve more or less than the remainder of the eye? Directly back of the cornea is the colored part of the eye, called the *iris.* In the center of the iris is a hole, the *pupil.* Compare the size of the pupil when in a bright light with its size in a dim light. From this, what do you conclude is the function of the iris? Is its action voluntary or involuntary?

Now examine the model. Locate the parts mentioned above. The wall of the eyeball consists of three layers: the outer, composed of the *sclerotic* and the *cornea;* the middle, the black *choroid,* and in front the colored *iris;* and the inner, the *retina.* Note where the optic nerve enters the two outer coats and spreads out to form the retina. Just back of the pupil note the convex *crystalline lens.* The space between the lens and the cornea is filled with a liquid, the *aqueous humor;* and the larger space back of the lens is filled with a jelly-like mass, the *vitreous humor.* Draw a section of the eye, showing parts given above.

On the outside of the model locate the six muscles used in moving the eyeball. From the position of each determine what motions it gives to the eyeball.

B. Hold your pencil point at several different distances from your eye. At what distance can you see it most comfortably and most clearly? From this distance move the pencil toward the eye. At what

distance from the eye does it become indistinct, or fringed with a haze?

Hold a book with the edge placed directly toward you. Close the left eye and look at the book. Then close the right eye and look at it again. Then look at it with both eyes open. What differences do you note? How do you account for these differences?

In front of a lens, both of whose faces are convex, place a lighted candle or a gas flame. Back of the lens place a piece of paper to form a screen. Move the paper back and forth until a distinct image of the flame is seen upon the paper. What effect does it have upon the image formed to move the flame nearer, or farther away from the lens?

Adjust the apparatus again so that a distinct image is formed on the screen. Remove the lens and put in its place one which is more convex. Which way must the screen be moved to secure a distinct image? Repeat this experiment, using a lens which is less convex than the first one used; also use one which is concave.

Exercise 92. Organ of Hearing.

Object: A study of the ear.

Apparatus

Model of the ear

Directions: The ear is made up of an external ear, a middle ear, and an inner ear. On the model examine the external ear. Note the *pinna,* the oval, expanded,

funnel-shaped portion. Leading from this is a canal. Across the inner end of this canal, or tube, is stretched a thin membrane, known as the *ear drum* or *tympanic membrane.* Examine the middle ear. What is its size? How is it connected with the pharynx? What is the name of this tube? What is its function? On the inner surface of the cavity of the middle ear and separating it from the inner ear are two small openings covered with membrane. Across the cavity of the middle ear is a chain of three small bones, called from their shape the hammer (*malleus*), the anvil (*incus*), and the stirrup (*stapes*) bones. How are they placed with reference to each other? With reference to the outer and inner ears? Can you suggest any functions for them? The inner ear is formed by an irregular cavity in the temporal bone, and is called the *bony labyrinth.* It is lined with a membrane which secretes a fluid. It is divided into three parts. The middle part is the vestibule. The part back of this consists of three tubes, the *semi-circular canals.* The part in front of the vestibule is a single tube coiled like a snail shell and called the *cochlea.* The branches of the auditory nerve enter this bony labyrinth. Locate the parts of the inner ear on the model. Draw a diagram showing the relation of the parts in the ear.